Technical Report 413

LEVEL

A DIGITAL SIMULATION MODEL OF MESSAGE HANDLING IN THE TACTICAL OPERATIONS SYSTEM

IV. Model Integration with CASE and SAMTOS

W. Rick Leahy, Arthur I. Siegel, J. Jay Wolf
Applied Psychological Services, Inc.

DTIC
ELECTED
JUL 1 0 1980
C

HUMAN FACTORS TECHNICAL AREA

ari

U. S. Army

Research Institute for the Behavioral and Social Sciences

October 1979

80 7 10 036

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the
Deputy Chief of Staff for Personnel

JOSEPH ZEIDNER
Technical Director

WILLIAM L. HAUSER
Colonel, U S Army
Commander

Research accomplished for the
Department of the Army

Applied Psychological Services, Inc.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report 413	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A DIGITAL SIMULATION MODEL OF MESSAGE HANDLING IN THE TACTICAL OPERATIONS SYSTEM. IV. MODEL INTEGRATION WITH CASE AND SAMTOS.		5. TYPE OF REPORT & PERIOD COVERED Final Report. 1 Jul 74 — 31 Dec 75
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) W. Rick Leahy, Arthur I. Siegel, and J. Jay Wolf		8. CONTRACT OR GRANT NUMBER(s) DAHC 19-75-C-0001
9. PERFORMING ORGANIZATION NAME AND ADDRESS Applied Psychological Services, Inc. Science Center Wayne, PA 19087		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q762722A765
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333		12. REPORT DATE Oct 79
		13. NUMBER OF PAGES 60
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

--

18. SUPPLEMENTARY NOTES

--

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Modeling	Operations analysis
Computer simulation	Information systems
System analysis	Human factors

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The human performance oriented computer simulation, called MANMOD, of the U.S. Army's Tactical Operations System (TOS), was modified and extended to allow increased capability and generality. The modifications and extensions included but were not limited to: (1) incorporation of the capability to simulate error message receipt and processing, (2) interaction and integration with a modified CASE model and with the SAMTOS model which principally simulate TOS equipment functions, and (3) implementation of the MANMOD on

(Continued)

DD FORM 1473 1 JAN 73   EDITION OF 1 NOV 65 IS OBSOLETE

Item 20 (Continued)

the Univac 1108 computer system. The modified MANMOD was tested relative
to sensitivity and reasonableness of output. The evidence supports the
use of the model for a number of functions relative to system design,
training requirements and objectives derivation, personnel requirements,
and tradeoffs.

Accession For

NTIS GRA&I
DDC TAB
Unannounced
Justification

By
Distribution/
Availability Codes

Dist | Avail and/or
     | special

A

A DIGITAL SIMULATION MODEL OF MESSAGE HANDLING IN THE TACTICAL OPERATIONS SYSTEM

IV. Model Integration with CASE and SAMTOS

W. Rick Leahy, Arthur I. Siegel, J. Jay Wolf
Applied Psychological Services, Inc.

Submitted by:
Edgar M. Johnson, Chief
HUMAN FACTORS TECHNICAL AREA

Approved by:

Milton S. Katz, Acting Director
ORGANIZATIONS AND SYSTEMS
RESEARCH LABORATORY

ARI Research Reports and Technical Reports are intended for sponsors of
R&D tasks and for other research and military agencies. Any findings ready
for implementation at the time of publication are presented in the last part
of the Brief. Upon completion of a major phase of the task, formal recom-
mendations for official action normally are conveyed to appropriate military
agencies by briefing or Disposition Form.
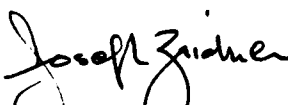
FOREWORD

The Human Factors Technical Area of the Army Research Institute (ARI) is concerned with the human resource demands of increasingly complex battlefield systems designed to acquire, transmit, process, disseminate, and utilize information. Research focuses on human performance problems related to interactions within command-and-control centers as well as issues of system development, performance, effectiveness, and efficiency. It is concerned with such areas as software development, topographic products and procedures, tactical symbology, user-oriented systems, information management, staff operations and procedures, decision support, and sensor systems integration and utilization.

Of special interest are the human factors problems related to the integration of human functions into information-processing systems and to the harmonizing of system components, personnel, and operations in a battlefield environment. To incorporate human functions and performance into simulated system operations, a research program at ARI developed a computer simulation of a generalized human information processing model (MANMOD). MANMOD permits study of system operations and performance under prescribed as well as alternative personnel and equipment configurations.

This report describes the interface of MANMOD with two computer models, CASE and SAMTOS, of the Army's tactical operations system (TOS). This effort supported the Army's cost-effectiveness analysis of TOS (CEATOS) and the investigation of alternative TOS configurations. Earlier reports in the series described sequential versions of MANMOD: batch processing in Volume I (ARI technical report TR-77-A23), on-line processing in Volume II (TR-77-A24), and interactive in Volume III (TR-77-A25). ARI Technical Report 414 (Volume V) provides a user's guide to the integrated MANMOD/CASE/SAMTOS simulation described here in Volume IV. Also, ARI publications TR-77-A22 and Technical Report 407 describe a second-generation model, NETMAN, developed on the basis of MANMOD research.

Research on systems integration and operations is conducted as an in-house effort augmented through contracts with organizations selected for their unique capabilities and facilities for research and development on human performance and computer simulation. This report represents research by personnel from ARI and Applied Psychological Services, Inc., under contract DAHC19-75-C-0001. The effort is responsive to general requirements of Army Project 2Q762722A765 and to special requirements of the U.S. Army Combined Arms Combat Development Activity. Special requirements are contained in Human Resources Need 76-161, "MAN MODEL interface with other CEATOS support models."

JOSEPH ZEIDNER
Technical Director

v

A DIGITAL SIMULATION MODEL OF MESSAGE HANDLING IN THE TACTICAL OPERATIONS
SYSTEM: IV. Model Integration with CASE and SAMTOS

BRIEF

Requirement:

To improve the SAMTOS computer model of the Army's tactical operations
system (TOS) for cost-effectiveness analysis, by enhancing its capability
to simulate the information-processing performance of personnel. CASE
simulates the TOS communications network and estimates the effects on TOS
performance of number of components and network variations. SAMTOS
simulates the TOS computer hardware and software. MANMOD simulates activ-
ities within a communications station and assesses the effects of operator
characteristics on message-handling performance, to provide estimates of
human performance parameters.

Procedure:

CASE was interfaced with MANMOD to permit the transfer of network
equipment parameter estimates to MANMOD. MANMOD's human performance
parameters were input to SAMTOS. In addition, MANMOD was enhanced to
improve the simulation of errors in message processing. All MANMOD modifi-
cations were tested for sensitivity and reasonableness.

Product:

Integration of the three simulations required only minor modifications
to CASE and none to SAMTOS. Sensitivity tests of the previously validated
MANMOD supported the effectiveness of the modifications. All changes in
MANMOD output parameters were in the expected directions, although in the
absence of appropriate criterion data the magnitude of those changes was
not tested.

Utilization:

The integration of the three computer simulations provides a useful
tool for analyzing and designing alternative system configurations. Within
the limits imposed by the lack of appropriate data for validating the
model, system effectiveness and other figures of merit can be obtained for
alternative system configurations. These alternatives can reflect differences
in personnel characteristics, manning levels, message traffic loads,
equipment capabilities, performance, or message types. Results can provide
insights on equipment design, training and personnel requirements, and the
tradeoffs necessary for optimum cost effectiveness.

TABLE OF CONTENTS

TABLE OF FIGURES

CHAPTER I

INTRODUCTION

This report constitutes the fourth in a series which documents the development and evaluation of the MANMOD, a stochastic, digital simulation model for simulating the acts and behaviors of the personnel involved in the operation of the U. S. Army's Tactical Operations System (TOS).

The TOS, although still in the developmental and test stages, is intended as a part of an overall integrated Battlefield Control System (IBCS), in which it will serve the information collection and dissemination functions. The information system is also intended to provide transmission of orders, information requests, and practically any information concerning the battlefield situation. The system design, as currently conceived, is documented in some detail in Tactical Operations System: Operable Segment, System Engineering Study Report (1972). The TOS has been tested in different configurations in the field both in Europe and the U. S. A. A simplified TOS has been experimentally studied in the laboratory (e. g., Baker, 1970; Baker, Mace, & McKendry, 1969).

The MANMOD was designed to function in parallel with such experimental studies and complement their findings.

Other computer simulation models (CASE and SAMTOS) of the TOS have been developed elsewhere. These models approach the simulation in different ways and possess different objectives from the MANMOD. The MANMOD generally allows the capability to study the effects of varying operator and manning considerations on message processing effectiveness. The CASE and the SAMTOS models are more concerned with equipment functions with (more or less) constant human operators in the loop.

Initial MANMOD Development

In the initial MANMOD development, the model was organized so as to assess the effects of varying operator characteristics on message processing speed and accuracy. Operator characteristics considered in this initial simulation model were:

- speed
- precision
- level of aspiration
- stress threshold
- fatigue

The initial development also allowed study and analysis of the effects of message characteristics such as:

- arrival frequency
- arrival distribution
- length
- type
- priority

The output or description of the resulting simulation was partitioned in five ways in order to provide a complete picture of the simulation performance. These five categories are:

- manpower utilization
- message processing times
- effectiveness
- workload summary
- error summary

The model simulates the activities within a single communication station in the TOS field army situation. The station is manned by a single G-3 (operations) officer, and may include one or more action officers. These men receive messages of various types which are delivered to the station at times unknown in advance of the simulation. Their function is to screen incoming messages, decide on the order in which they are to be processed, and to select the appropriate message form to which they transform the content of each message to be entered into the TOS data bank. One class of simulated messages is "generated" by the MANMOD at random times. The

other class involves situation reports which are assumed to arrive only during the last quarter of a given hour. To process both classes of message further, the performance of one or more UIOD operators is simulated. Working from the queue of message forms prepared by the officers, the UIOD enter each message into the TOS system using a keyboard and CRT edit/verify device. The purpose of the model is to simulate these personnel on an hour-by-hour basis over a single work shift.

Although the above general task assignment to operators and the sequencing thereof is the current approach, the MANMOD treats these as soft. Since they are controlled by input data, they may be readily changed.

The computer program written in the FORTRAN IV language was designed for the CDC 3300 computer. The model handles up to 6 men of 2 types (any combination of Action Officers and UIOD's), 4 types of operator errors, 7 types of messages, and 5 message priority classifications.

Figure 1, taken from Siegel, Wolf, and Leahy (1973a), shows the subroutines and their interrelation with the main processing flow. Following data read-in, there is an optional recording of the input data. Conditions are then reset (circle b of Figure 1) for the start of simulation for a new TOS shift. The backlog subroutine (BAKLOG) generates data representing messages in the Action Officer's "in-box" at the start of each iteration. At circle c of Figure 1, following reset of counters and registers for record keeping of hourly results, the message generation subroutine develops data representing messages which will arrive during the coming hour. These are merged with the backlog in order by time of arrival, and the contents of this hourly message queue is optionally recorded. At circle d of Figure 1, the processing of each message in turn by a single operator (either G-3, Action Officer, or UIOD operator) begins. The Man Determination Subroutine selects the appropriate man to simulate next, and determines the next available appropriate message for this selected man to process. The operator stress and aspiration conditions applicable to that operator message situation are calculated next. At this point (circle j), all data are available for the detailed task element-by-task element simulation for the message and operator selected. This is accomplished by the Operator Processing Subroutine, which manipulates mission task analysis data. During this subroutine, the detailed results of the simulation of the performance of each task element, as well as the summary results for this one message, may be optionally recorded for printing.
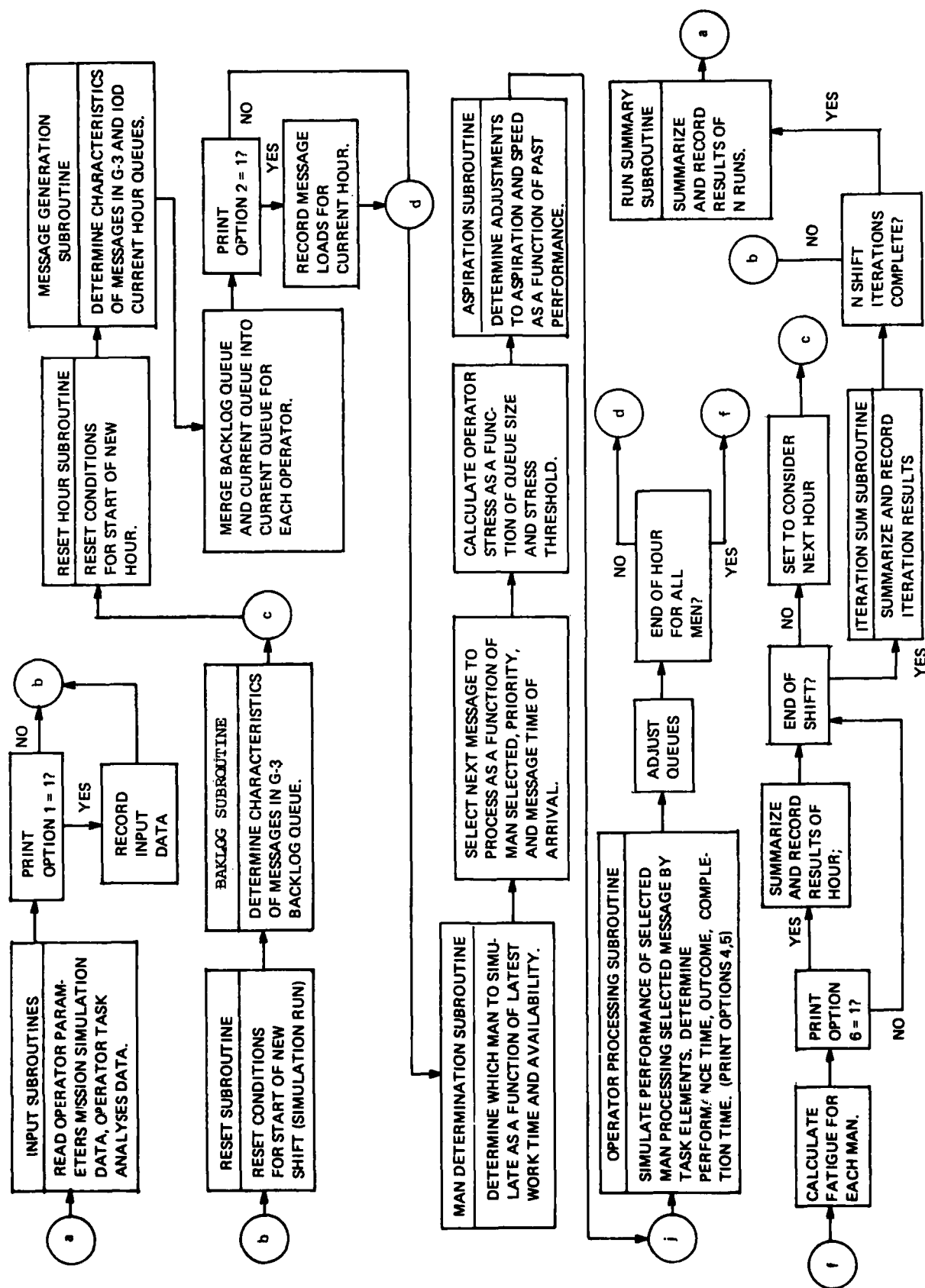
FIGURE 1. SUMMARY OF INITIAL MANMOD FLOW LOGICS (FROM SIEGEL, WOLF, AND LEAHY (1973)).

Following this, queues are adjusted and the cycle repeats back to circle d for processing of all messages which can be handled before the next one hour segment is completed. When the end of an hour condition is reached for all men, the results of the hour's simulated activity are optionally printed. The process of simulating in one hour segments is repeated (back to circle c) until the simulation of one iteration of an entire shift is completed. When a shift iteration is finished, the iteration summary subroutine generates summary data over the shift. The process is repeated (back to circle b) for each iteration and after all iterations are complete, the run summary subroutine summarizes and records all the pertinent performance figures to complete a simulation run. Multiple runs are processed sequentially through the entire process by returning to the input subroutines at circle a of Figure 1 and processing as many sets of data as are provided as input.

In the first stage of the development of MANMOD, the model's output was verified through a comparison with independently collected criterion data. Substantial correspondence was indicated between the criterion data and the predictions of MANMOD.

Further Development of MANMOD

Having achieved a simulation which appeared to possess merit, the initial version of MANMOD was revised to allow online modification of simulation parameters through an interactive terminal. This modification allowed for increased flexibility in model employment. The original model called for card/tape data input and allowed for output in the usual printed computer tabulation form. The revision allowed an active "conversation" between the model and its user because the revision provided online data input and immediate presentation of results on the terminal's cathode ray tube. With the interactive feature, the model's user could easily and quickly explore alternatives and variations suggested by a set of simulation runs.

Additional enhancements incorporated during this first model revision included:

1. revision of the responsiveness formula in the system effectiveness calculation and a correction of the formula for calculating the system effectiveness index

5

2. addition of the capability to generate more than one TOS message from a single input message

3. correction of the calculation for the number of un-detected errors

4. incorporation of the effects of message priority on operator stress

5. extension of the existing limit from one shift of up to 12 hours to as long as 24 hours (including up to four shifts)

6. improvement in the content and format of the printed output

In the third developmental phase, the interactive model was extended to process simultaneously a combination of real data as provided by physical simulation and computer simulation data. In this mode, an experimental subject performs part of the task(s) simulated. The subject data are recorded on disk and combined with the computer simulation generated data to provide an integrated result. This mode of operation was called the subject interactive mode. In this mode, an experimenter seated at a terminal can:

1. select, enter, and verify run and operator parameters

2. specify number and cathode ray tube assignment of subjects

3. designate which tasks in a task analysis list a subject is to perform

4. monitor the messages generated and specify those which are to be performed by subjects

5. monitor results of each hour's processing by both computer simulation and subject

6. observe subject actions and indicate times of start and end of tasks

7. monitor subject performance times

Figure 2 presents the flow of data in this computer-experimenter-subject interactive mode.
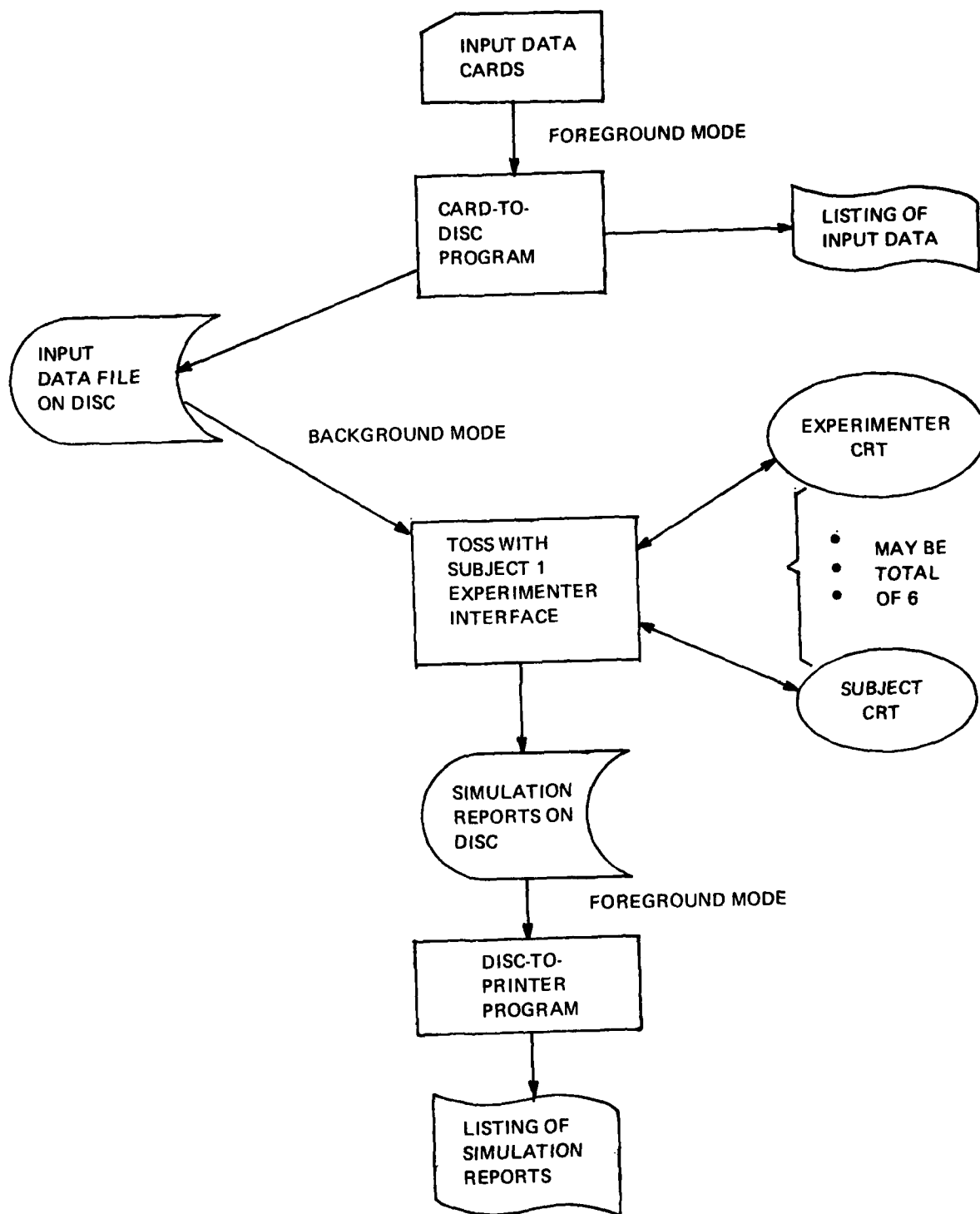
6

FIGURE 2. SYSTEM FLOW FOR THE COMPUTER-EXPERIMENTER, SUBJECT INTERACTIVE MODE

7

A second part of the subject interactive mode allowed the computer to call the subject interactive data from disk, average it to provide new human performance data, and then use these data in a new simulation which may be stochastically repeated across many varied iterations. The results from such a stochastic combination of events across many iterations have been found to provide a more consistent, representative, and replicable picture of simulated events.

Purpose of Present Work

The general purpose of the effort here reported was to produce a more useful and more powerful version of the MANMOD for simulating the TOS network. The specific purposes included:

- allowing for automatic transfer of data between MANMOD and complementary simulation models

- modifying the MANMOD so that it can be run on the U 1103 computer system

- increasing the verisimilitude of the model through incorporation of error message evaluation and interruption features

The details of this work are presented in Chapter II of this report.

CHAPTER II

PROGRAM DETAILS

As stated at the conclusion of Chapter I, the present program possessed a diversified, but interrelated, set of purposes. Achievement of each of these purposes provides the Army with a fully articulated and integrated model which allows simulation of the TOS system in a highly flexible manner. The reader who is interested in a complete guide to the operational and functional details for the final model should consult the User's Guide to the Integrated MANMOD/CASE/SAMTOS Computer Simulation, which forms a separate appendix to the present technical report.

Data Transfer between Various Models

Over the past few years, three separate models have been developed to simulate various aspects of the TOS. One such model, MANMOD, was briefly described above. Another model, the Communications Analysis Simulation and Evaluation (CASE) model simulates a large network communications system, including the TOS system, as well as more commonly used phone and written message systems. The model was designed to determine the effects of number of components and network variations on overall system function.

A third computer model, SAMTOS, was developed by the U. S. Army Electronics Command, and has already gone through several revisions. SAMTOS principally locates queuing and hardware bottlenecks within a system as a function of such variables as transmission rate and number of channels. Although some human performance effects, such as operator keying rate, are simulated, the human operator is treated within this model as a static component.

The logic for the integration of MANMOD, CASE, and SAMTOS is presented in Figure 3. Specifically, the CASE model was revised by the Systems Analysis Section, Plans and Analysis Division, U. S. Army Electronics Command, so that it can be implemented on the U 1108 computer system. In completing this revision, the CASE model aspects of interest for the required integration were programmed in the GERTS programming language. This language is particularly useful when one or more networks are involved in a simulation. Full details of the revised CASE are presented in Appendix A to this report. In the present application, the system delay time output of the revised CASE model is stored in a file accessible by MANMOD. Accordingly,
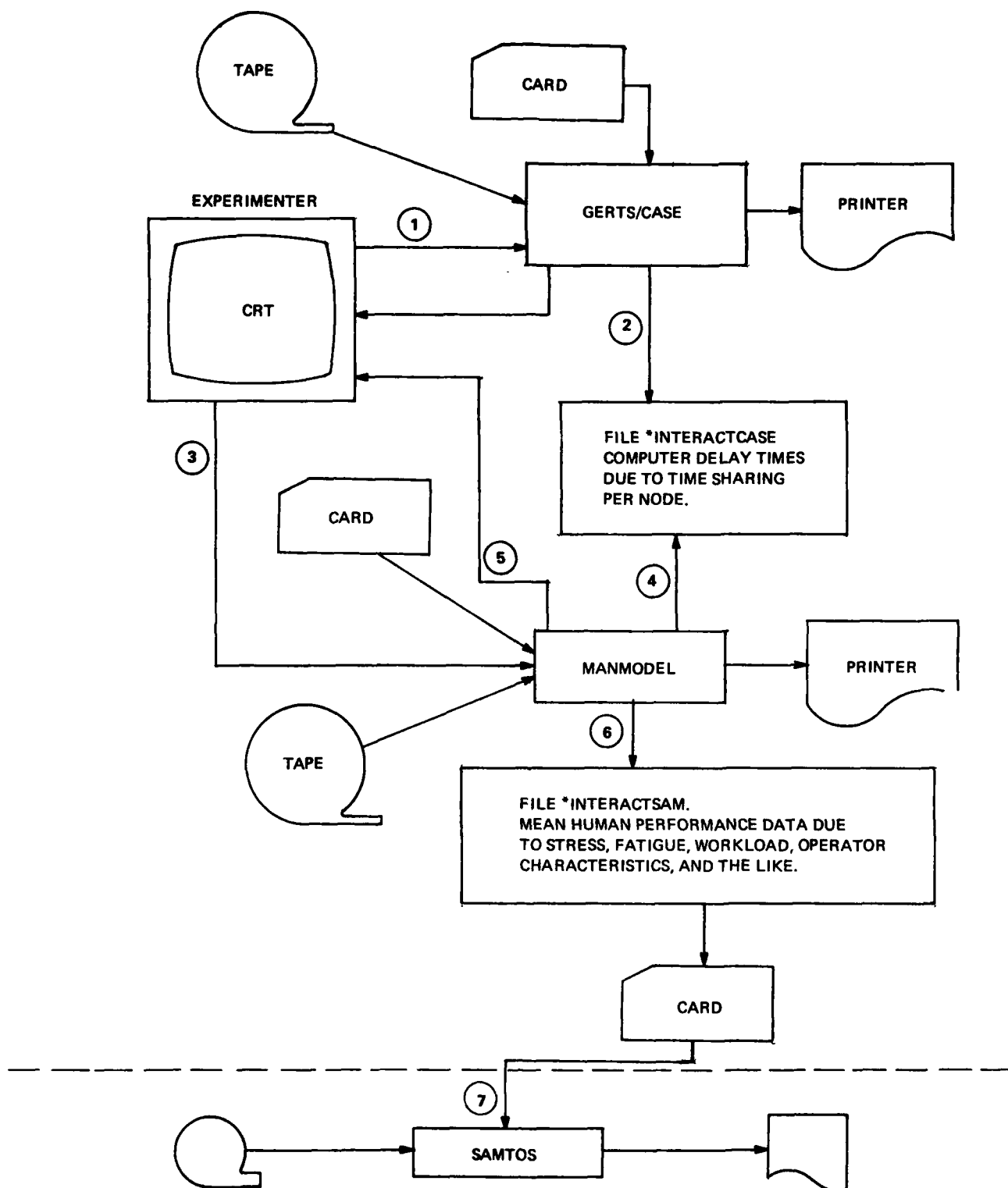
FIGURE 3. COUPLING BETWEEN CASE, MANMODEL, AND SAMTOS SIMULATIONS

10

MANMOD accepts the system delay time generation of CASE and employs these delay time data in its normal simulation of the acts and behaviors of the operators as they process incoming messages. Finally, the output of the combined CASE and MANMOD can be printed and punched on cards in such a manner that the punched cards can be used as direct entry into SAMTOS. In this manner, a simulation is accomplished which consolidates the three separate models and which incorporates the major features and advantages of each--the sophisticated delay time generation of CASE, the human action simulation of MANMOD, and the queuing effects and variable load simulation of SAMTOS.

Although the integrated model can be processed in its entirety through card input, it is also designed to be controlled by user interaction through a terminal. As shown at circle 1 of Figure 3, the revised CASE program is called first. This activation causes several files to be read, and the program begins. After the entry of customary parameters, the user is queried as to whether or not a file should be written for MANMOD. If the user so indicates, the CASE simulation proceeds. After the CASE simulation is completed, the resulting delay time data are displayed to the user's terminal. The user may, at his option, have the regular output file printed or wait until some later time. The revised CASE program writes the delay time data to a special data file (*INTERACTCASE) as well as to the user's terminal.

The user must allow the CASE simulation to proceed to normal termination and then call the MANMOD. Once activated, the MANMOD executes its normal card input routines and then enters an interactive mode. This mode allows the user to examine and change parameters. The user, at this time, can either call in the CASE generated data from file *INTERACTCASE or he can provide his own data for these variables. When the interaction data are called, the nodes of interest must be specified. Then the mean durations of the delays are computed and displayed to the experimenter.

The option to write data to file *INTERACTSAM is also provided to the user. These data consist of human performance times due to stress, fatigue, workload, and operator characteristics. This file can be printed or punched on cards for the use of the SAMTOS model in its simulations.

The integrated model is now operational on the U 1108 system and is fully documented in the User's Guide to the Integrated MANMOD/CASE/ SAMTOS Computer Simulation.

11

Error Message Processing and Interruption
Feature Augmentation of MANMOD

While MANMOD has been considered to incorporate sufficient detail to allow simulation of most aspects of human activity during message processing in the TOS system, two features, not previously or only minimally considered, were believed to be of sufficient import as to warrant consideration for inclusion or expansion in the MANMOD simulation. These features were: error message processing and interruption. Each of these, together with the appropriate description of the method of implementation in the MANMOD, is described in the succeeding paragraphs.

Error Message Processing

Whenever an operator enters a message into the TOS computer system, the message is either acknowledged or rejected. In the case of a rejected message, an "error message" is displayed to the operator. Examples of possible error messages are shown in Figure 4. These messages are quite brief. Although they identify the problem in some general manner, they do not indicate the corrective action required. When he receives an error message, the operator must read the error message, determine the required correction, make the correction, and enter a modified message. When the operator transmits the modified message, it may or may not be correct. On occasion, the appropriate correction may not be known to the operator. In this case, the operator will consult other available courses such as other personnel or available manuals and documentation.

Previously an error message processing feature was included in the MANMOD simulation. However, this simulation aspect was somewhat barren. Accordingly, a new error message processing logic was developed and incorporated into the MANMOD.

In its current form, the error message processing subroutine is based on two separate concepts--the vocalic center group concept and decision making in a choice decision situation.

The Vocalic Center Group Concept

In order to process an error message the operator must first recognize the meaning of the message. Having extracted the meaning, he must then derive an appropriate correction action pathway.

```
UNIT NOT FOUND

ORIG-CODE DUPLICATES EXISTING ENTRY

TASK FORCE NAME CURRENTLY IN USE

DUPLICATE NAME-OR-NO FOR TYPE DATA

NAMED ARE NOT FOUND

VICINITY OF NEEDED FOR NEW SITREP

MESSAGE OUTDATED

ONLY G2 MAY USE EWFA
```

Figure 4.   Examples of error messages.

The perception of the meaning aspect of the simulation is based on the Vocalic Center Group (VCG) concept reported by Spoehr and Smith (1973) and Smith and Spoehr (1974). In this concept:

> ...when a word is presented, features of each letter
> position are first extracted and then matched to in-
> dividual letter categories. The categorized informa-
> tion is then placed in a sensory store. The function
> of this store is to maintain the visual information
> long enough for some orthographically dependent pars-
> ing process to segment the letter string into higher-
> order units, called VCGs, so that a subsequent trans-
> lation process can assign an acoustical code to each
> unit. It is not until the translation process is com-
> pleted that perceptual processing is assumed to be
> over (Smith & Spoehr, 1974, p.260).

A vocalic center group is defined by Smith and Spoehr as "a letter sequence that contains one vocalic element, a single vowel or dipthong, and from zero to three consonants or semi-consonantal elements preceding or following the vocalic element (p. 260)."

To derive the number of vocalic center groups in a word, Smith and Spoehr present a number of parsing rules. Spoehr and Smith (1972) demonstrated that any letter string that forms a single vocalic center group is more perceptible than words containing two vocalic center groups.

We assume that an increase in the number of vocalic center groups within an error message is associated with an increase in the complexity and in the ambiguity of a message. The effect of increasing ambiguity within an error message is assumed to decrease the probability that an error message will be followed by an immediate revision of the UIOD entered message.

Decision Making

To simulate the decision making aspect of the error message correction, a random walk model is employed (Lansing, 1968). Figure 5 shows an example of this model.

Solution No Solution

A   B   C   D   E

Figure 5. Random walk process.

14

Five points, labeled A through E, are shown with interconnecting lines. A and E are called absorbing states which in our usage correspond to arriving at the right (A) solution or no (E) solution. Depending on the level of ambiguity in the error message, the decision process may be started at either B (very close to a solution), C (midway between solution and no solution), or D (very close to no solution). Probabilities are entered for the chances that a decision will move toward or away from a solution and the actual number of steps (stochastically determined during a simulation) are counted and used to compute the decision time.

Error Message Logic Flow

Figure 6 presents an overall flow chart of the error message processing. In the normal simulation mode, the number of incorrect transmissions is computed. An error message is randomly selected and processed. The level of ambiguity is computed and used in conjunction with the random walk model to determine whether or not a solution was reached and how much time was required. If a solution is not initially found the simulated operator starts exploring other avenues such as querying another operator or consulting reference materials. Data storage for up to ten options is provided and the time and probability descriptors of each option are provided as input data. Performing any of the information seeking options is assumed to reduce the level of ambiguity and initiate another random walk solution process.

Details of Error Message Processing

Figure 7 further details the error message processing. First, the presence of an operator error is noted and an error message is selected from a stored library of error messages. All error messages are assumed to be equally probable. Each error message possesses a predetermined number of vocalic center groups (NVG). These have been obtained by an actual count of the number of vocalic center groups in available error messages. The relationship between the number of vocalic center groups and starting point within the random walk is an input parameter. Positions 1 and 5 are the absorbing states within the random walk (i.e., termination points). Absorption at position 1 represents reaching a solution which is immediately implemented, while absorption at position 5 represents reaching no immediate solution, thereby necessitating reference to other sources of information. When a solution is found, this solution is used to modify the message and the message is transmitted. The time to enter this message modification is selected from a uniform distribution with a mean of AVCOR and a standard deviation of SDCOR (two new input parameters).
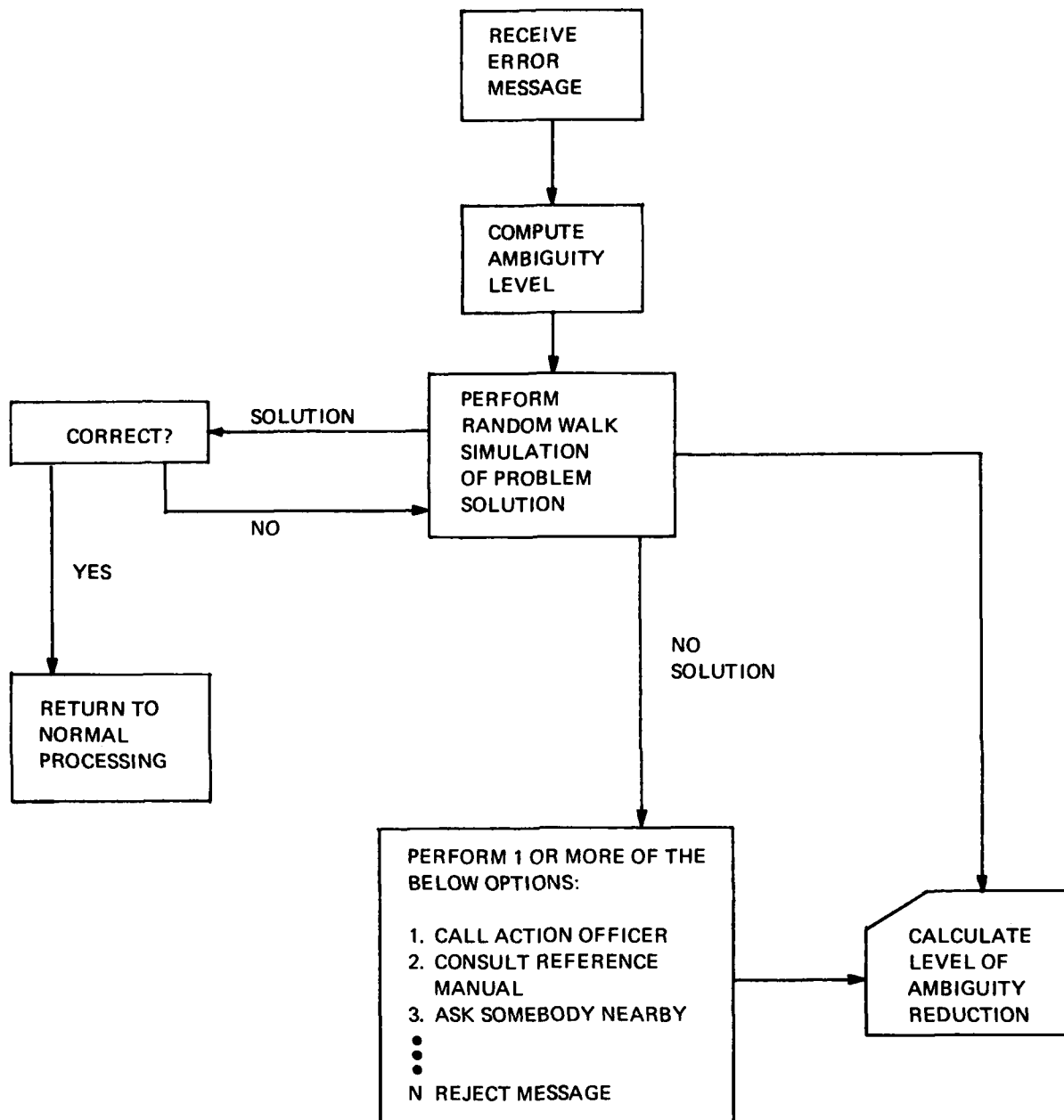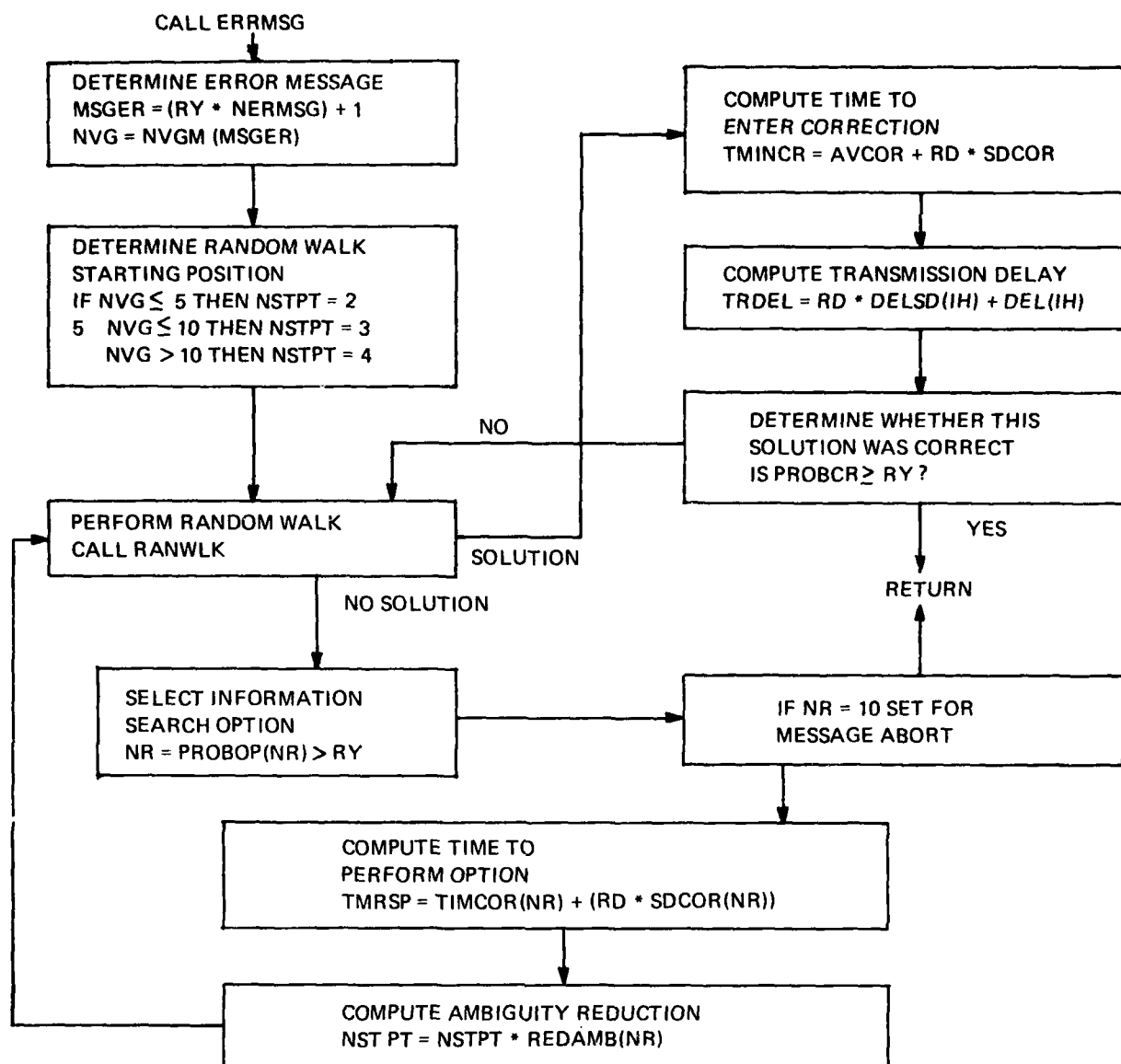
15

FIGURE 6. OVERALL ERROR MESSAGE LOGIC FLOW

16

CALL ERRMSG

DETERMINE ERROR MESSAGE
MSGER = (RY * NERMSG) + 1
NVG = NVGM (MSGER)

DETERMINE RANDOM WALK
STARTING POSITION
IF NVG ≤ 5 THEN NSTPT = 2
5   NVG ≤ 10 THEN NSTPT = 3
      NVG > 10 THEN NSTPT = 4

PERFORM RANDOM WALK
CALL RANWLK

SOLUTION

NO SOLUTION

SELECT INFORMATION
SEARCH OPTION
NR = PROBOP(NR) > RY

COMPUTE TIME TO
PERFORM OPTION
TMRSP = TIMCOR(NR) + (RD * SDCOR(NR))

COMPUTE AMBIGUITY REDUCTION
NST PT = NSTPT * REDAMB(NR)

COMPUTE TIME TO
ENTER CORRECTION
TMINCR = AVCOR + RD * SDCOR

COMPUTE TRANSMISSION DELAY
TRDEL = RD * DELSD(IH) + DEL(IH)

NO

DETERMINE WHETHER THIS
SOLUTION WAS CORRECT
IS PROBCR ≥ RY ?

YES

RETURN

IF NR = 10 SET FOR
MESSAGE ABORT

NERMSG	=	NUMBER OF AVAILABLE ERROR MESSAGES.
MSGER	=	ERROR MESSAGE SELECTED
NVG	=	NUMBER OF VOCALIC CENTER GROUPS
NSTPT	=	AMBIGUITY LEVEL: STARTING NODE IN RANDOM WALK WHERE 1 IS CORRECT SOLUTION AND 5 NO SOLUTION
PROBOP(10)	=	PROBABILITY OF SELECTION OF INFORMATION SEARCH OPTIONS
NOPTIO	=	NUMBER OPTIONS UP TO 10
NR	=	INFORMATION SEARCH OPTION SELECTED
TIMCOR(NR)	=	AVERAGE TIME TO PERFORM SEARCH OPTION
SDCOR(NR)	=	STANDARD DEVIATION OF TIMCOR
REDAMB(NR)	=	AMBIGUITY REDUCTION FACTOR OF OPTION NR
LEV(5)	=	LEVEL OF AMBIGUITY CUT OFF POINT

FIGURE 7. DETAILS OF ERROR MESSAGE PROCESSING

17

Another new input parameter - PROBCR - is used to determine whether or not the solution selected was correct, thereby satisfying the error message. If the error message is not satisfied the random walk is entered again.

The information search options are selected with a probability (PROBOP) equivalent to their likelihood of being used by an operator in a real TOS system. The options available are an input parameter. After an option is selected (e. g., glossary lookups, asking another operator), the time to exercise this option is randomly determined from a normal distribution with mean TIMCOR and standard deviation of SDCOR (new input). Each information search option has an ambiguity reduction factor associated with it. This ambiguity reduction factor is the amount that this source of information tends to move the decision process toward reaching a solution. It is expressed as a proportion and the product of this proportion and the previous starting point within the random walk represents the new starting point of the random walk. For example, if the process had started at 4, an ambiguity reduction of factor of .5 would move the starting point to 2. This effect would cause the probability of reaching a solution in the random walk to increase. After computing the new starting position, the random walk is started again. Again, solution or no solution may be reached, with the results described previously.

Details of Random Walk Processing

Detailed logic for the subroutine performing the random walk is shown in Figure 8. The starting point within the random walk is determined before the subroutine is entered. The first function within this subroutine is to initialize conditions. Next, a random number is selected to be compared with the probability of going toward a solution (PRBRT) and then with the probability of moving toward no solution (PRBWR). These probabilities are cumulative and may or may not sum to 1.0 since a standstill step may be performed and counted within the random walk. After each step is taken, the resulting position is tested to determine whether an absorbing state has been reached. If the absorbing state has not been reached, another random step is triggered and the step counter (NSTEPS) is increased. If an absorbing state has been reached, the outcome (NSOL) is noted and the time to reach the solution (TMCOMP) is computed as a function of the total number of steps and the time required to take each step (TSTEP). Two values are returned to subroutine error message: the outcome (solution reached or no solution reached), and the time required to reach the solution.
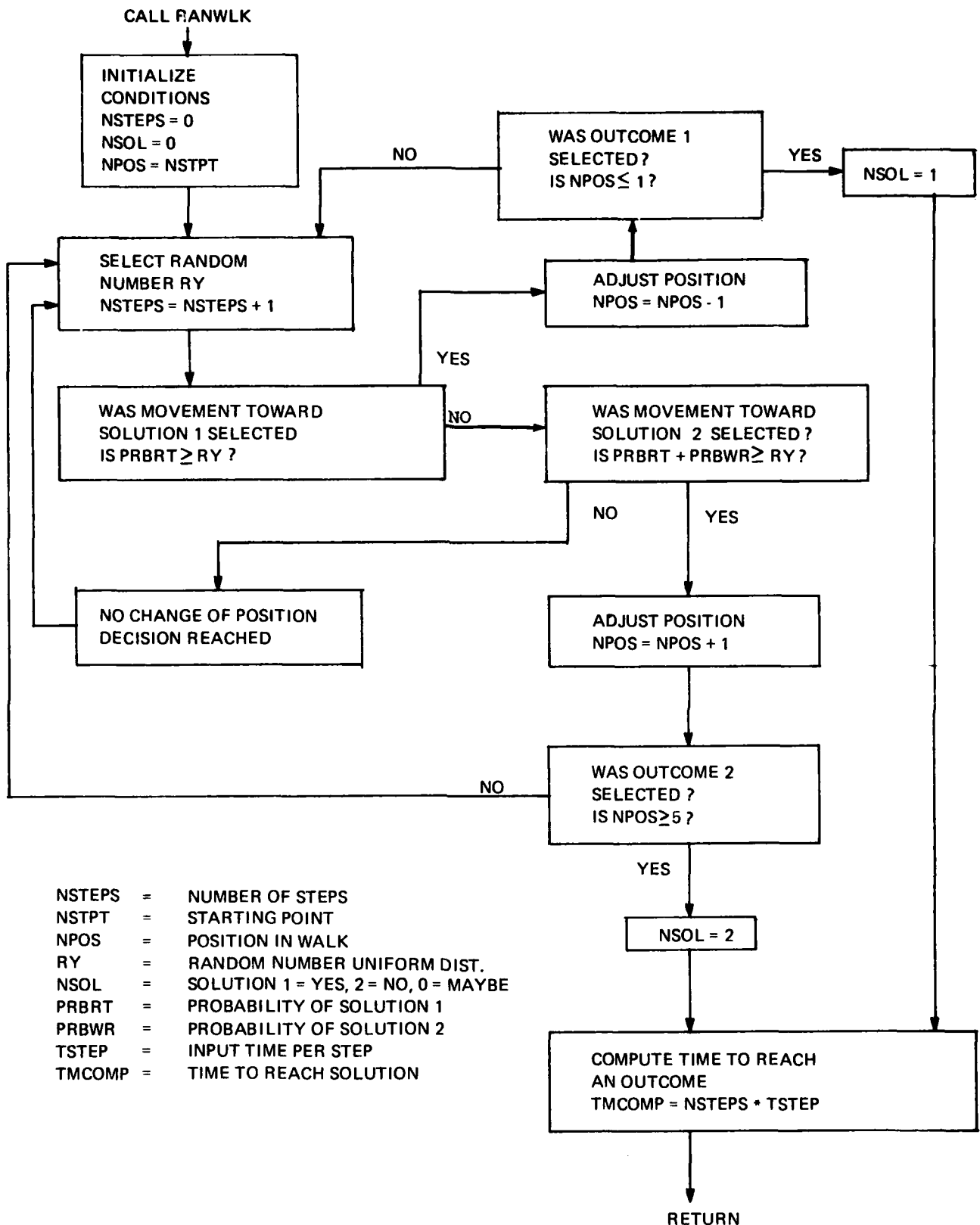
18

CALL RANWLK

INITIALIZE CONDITIONS
NSTEPS = 0
NSOL = 0
NPOS = NSTPT

WAS OUTCOME 1 SELECTED? IS NPOS ≤ 1?

NO

YES

NSOL = 1

SELECT RANDOM NUMBER RY
NSTEPS = NSTEPS + 1

ADJUST POSITION
NPOS = NPOS - 1

WAS MOVEMENT TOWARD SOLUTION 1 SELECTED
IS PRBRT ≥ RY ?

YES

NO

WAS MOVEMENT TOWARD SOLUTION 2 SELECTED ?
IS PRBRT + PRBWR ≥ RY ?

NO

YES

NO CHANGE OF POSITION DECISION REACHED

ADJUST POSITION
NPOS = NPOS + 1

WAS OUTCOME 2 SELECTED ?
IS NPOS ≥ 5 ?

NO

YES

NSOL = 2

NSTEPS   =   NUMBER OF STEPS
NSTPT   =   STARTING POINT
NPOS   =   POSITION IN WALK
RY   =   RANDOM NUMBER UNIFORM DIST.
NSOL   =   SOLUTION 1 = YES, 2 = NO, 0 = MAYBE
PRBRT   =   PROBABILITY OF SOLUTION 1
PRBWR   =   PROBABILITY OF SOLUTION 2
TSTEP   =   INPUT TIME PER STEP
TMCOMP   =   TIME TO REACH SOLUTION

COMPUTE TIME TO REACH AN OUTCOME
TMCOMP = NSTEPS * TSTEP

RETURN

FIGURE 8. DETAILS OF RANDOM WALK PROCESSING

19

Other MANMOD Modifications

In addition to the MANMOD modifications and coupling described above, a number of other changes in MANMOD were implemented:

Interruption due to incoming messages. The capability to simulate the interruption which results from an incoming message which possesses a higher order priority than a message being processed is a new feature which has been added to MANMOD. To accomplish this simulation aspect, the frequency of such interruptions along with the mean time duration and its standard deviation are provided as input. The time of occurrence of each interruption is randomly selected from a rectangular distribution and the interruption time duration is selected from a normal probability distribution on the basis of the input mean and standard deviation. Figure 9 presents the details of this logic.

Transmission Delay. Whenever a message is sent to the computer, a line becomes occupied. Because operator to computer lines are shared by a number of operators, some delay may occur before the computer receives and responds to the current message. Simulation of this delay has been added to the logic of MANMOD as shown in Figure 10. A type 6 task element is one which represents sending a message to the computer. In this case, a normal deviate is used to determine the transmission time, and this time is added to the processing time. This transmission delay feature is also shown in Figure 10 for the case in which a corrected message is inserted after the operator has received an error message. This new feature within the model is controlled by the new input variables delay [DEL(IH)] and delay standard deviation [DELSD(IH)]. These variables may be entered from cards, terminal, or read from the revised CASE generated file.
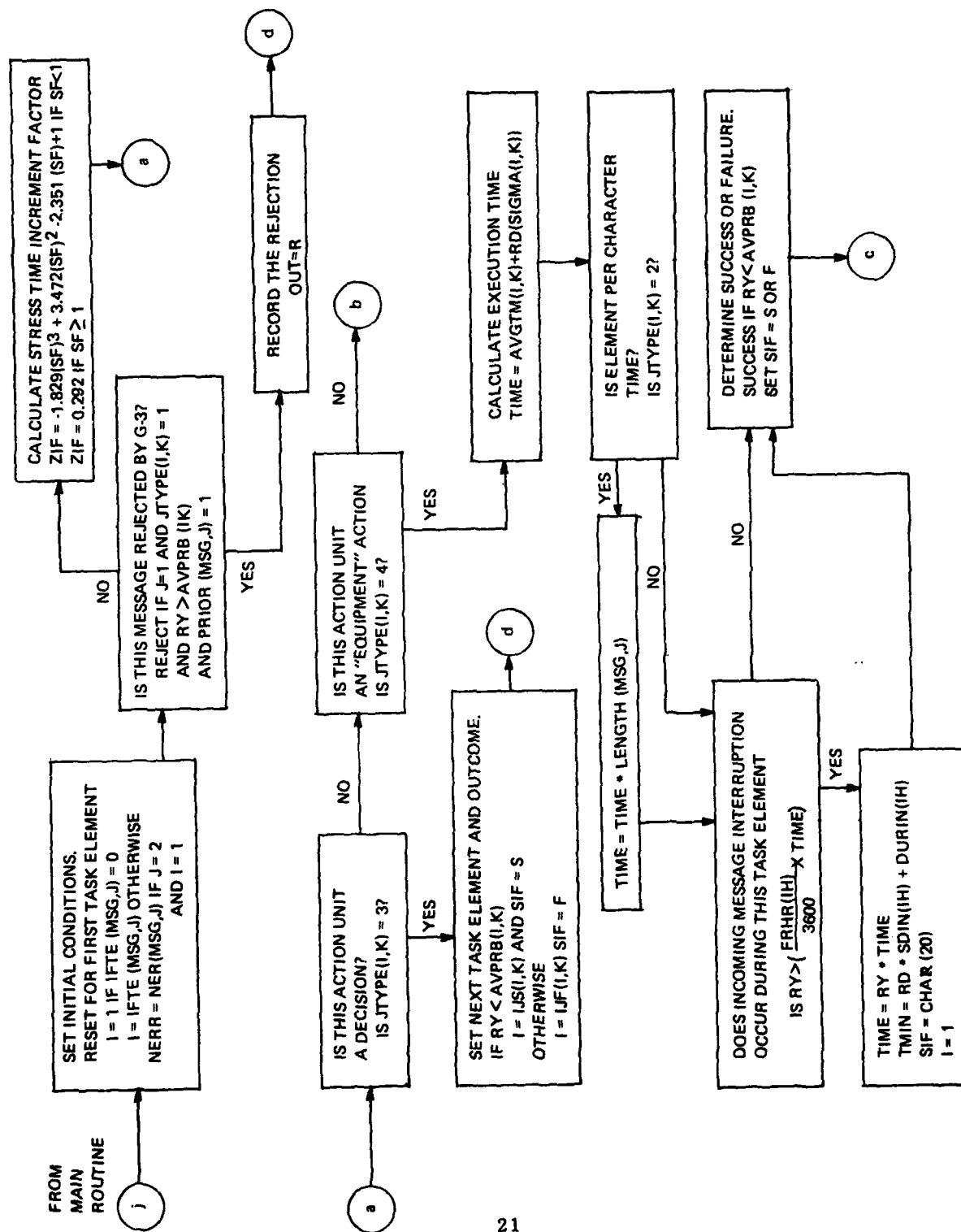
20

FIGURE 9. DETAILS OF INTERRUPTION DUE TO INCOMING MESSAGES LOGIC
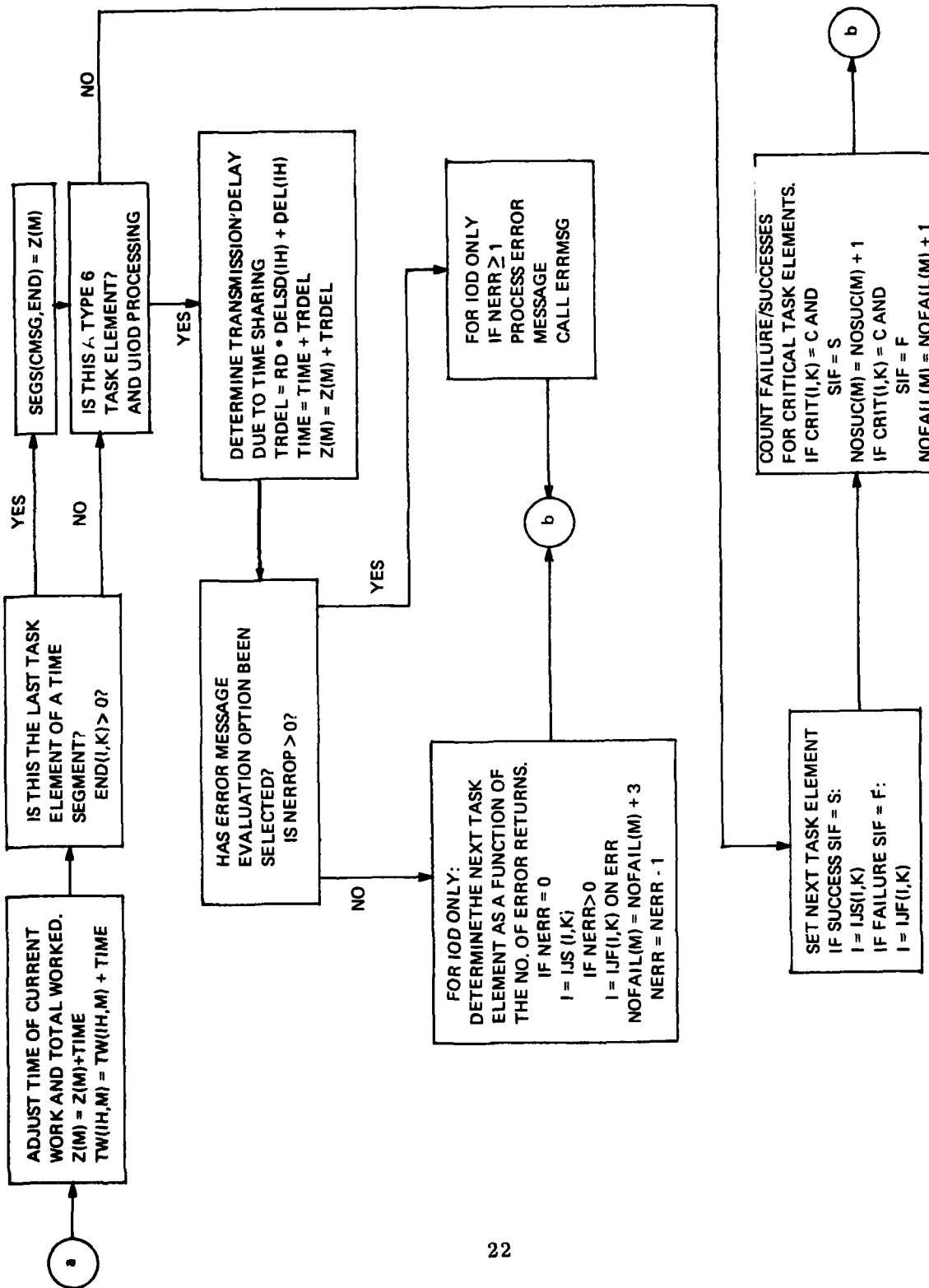
21

FIGURE 10. DETAILS OF TRANSMISSION LOGIC

22

CHAPTER III

SENSITIVITY TESTS

The new features incorporated into the MANMOD were tested for
sensitivity by varying input values over a wide range and measuring the ef-
fects of this variation on output. The test values were not selected for their
realism. Rather, they were selected to assess the extent to which the new
logic reflected appropriate variation to a range of conditions. Tests of this
kind are called *sensitivity tests* and provide an essential part of the evalua-
tion of a computer model. Adequate sensitivity is a necessary ingredient
in any computer model.

Error Message Logic Sensitivity

For the purposes of testing the sensitivity of the error message logic
(Figure 6), the error message handling routines of MANMOD were separated
from the rest of the model. Then a specified number of messages (an N of
100 error messages was used on all runs) could be executed without confound-
ing by the other aspects of the model.

Figure 11 presents the effects of the number of vocalic center groups
on error message processing time. As the number of vocalic center groups
increased from 4 to 16, the average time to process an error message in-
creased from 109 to 201 seconds. The effect was in the anticipated direction
and the anticipated linearity was evidenced in the low to midrange. Then the
effect became negatively accelerated at (about 13 vocalic center groups).
These data suggest that message meaning cognition will vary from about 1.5
minutes to over 3.0 minutes. This result seems extremely conservative (i. e.,
in the direction of an overestimate rather than an underestimate). However, the
processing time certainly reflects the input variation and the vocalic center
group variation seems to affect strongly simulation results.

. The random walk logic depends on an input entry relative to the prob-
ability of moving toward or away from a solution at any step of the walk. The
effects of varying this probability or random walk time was investigated by
varying this probability over a range of values from .10 to .90. The obtained
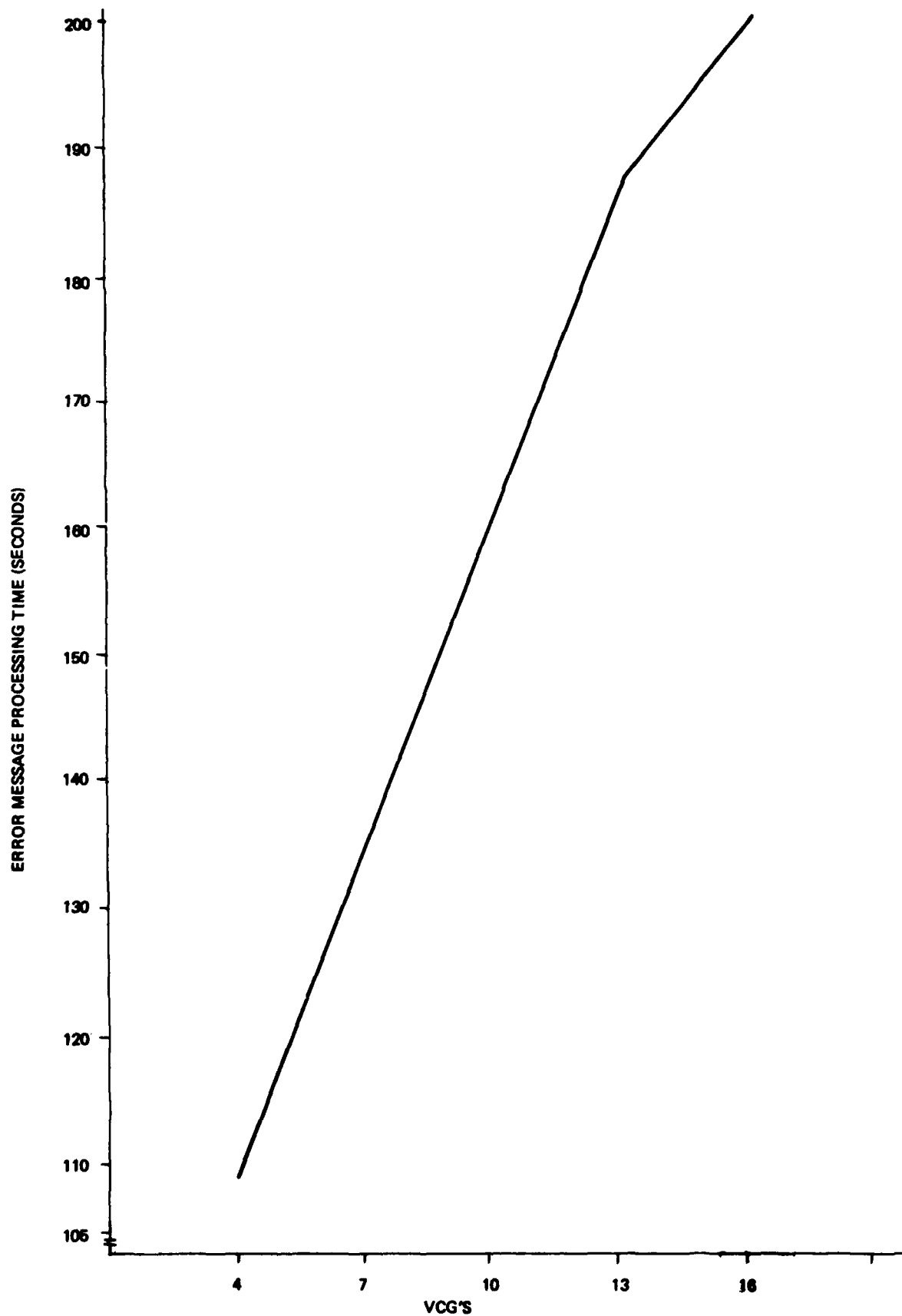result is presented in Figure 12.

23

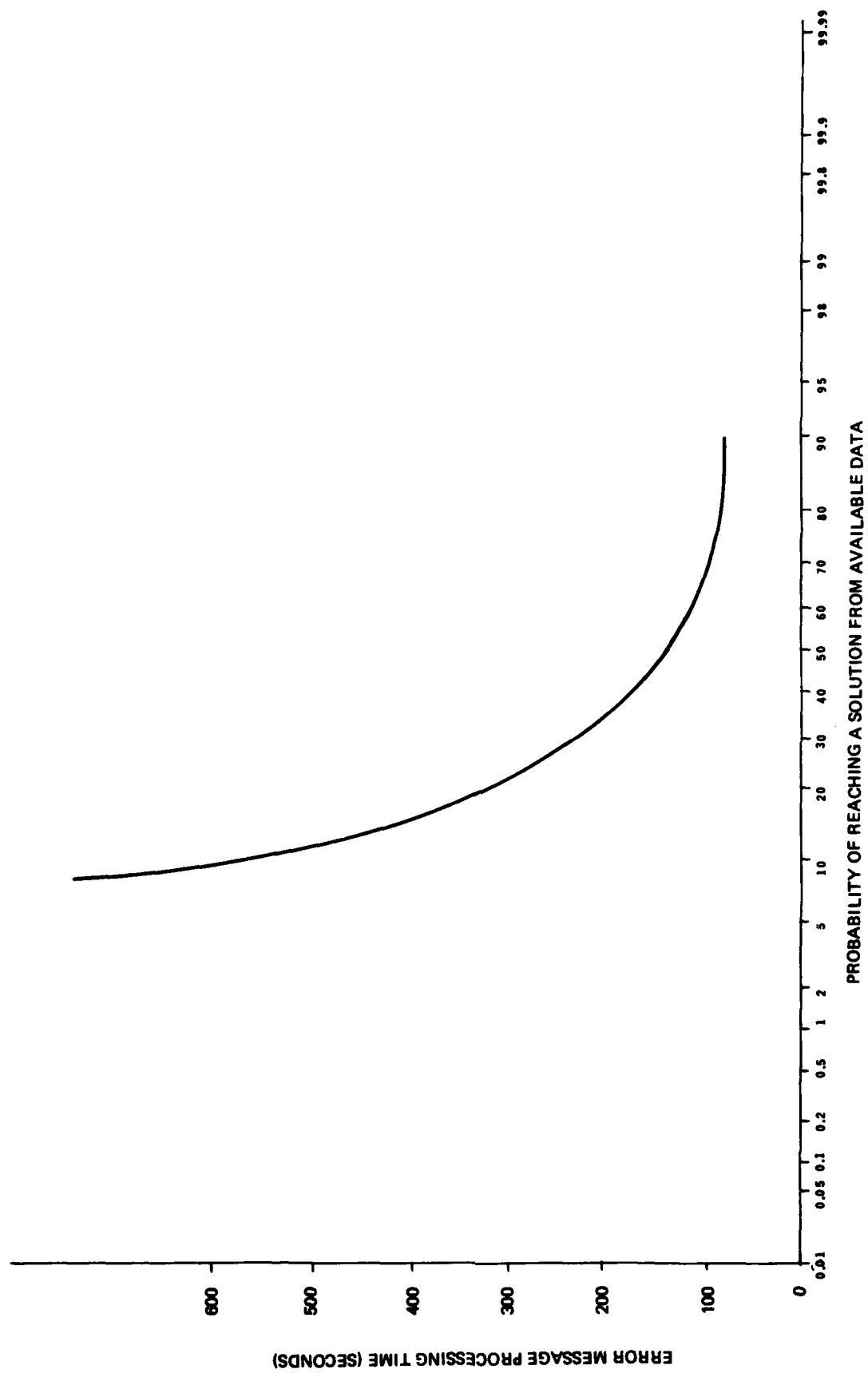Figure 11. EFFECT OF NUMBER OF VOCALIC CENTER GROUPS (VCG) ON ERROR PROCESSING TIME.

FIGURE 12. THE EFFECT OF THE PROBABILITY OF REACHING ANY SOLUTION (WITHIN THE RANDOM WALK) ON ERROR MESSAGE PROCESSING TIME

PROBABILITY OF REACHING A SOLUTION FROM AVAILABLE DATA

ERROR MESSAGE PROCESSING TIME (SECONDS)

25

As the probability of moving towards a solution decreased from
.9 to .1, the mean time for processing an error message increased from
96 to 551 seconds. The abscissa of Figure 12 is given in probabilities.
The obtained plot (Figure 12) shows the anticipated form because exit from
the random walk model through the information search route increases the
ambiguity reduction factor for the next entry into the random walk process.
Accordingly, there is a greater chance for exit through the solution route
on the second random walk trial than on the first. This makes common
sense. For example, an operator may receive several possible alternates
from a given information source. The choice among remaining alternates
should become less difficult as certain alternates are eliminated from con-
sideration.

Within the MANMOD logic, when a simulated operator rece.ves
and perceives the meaning of an error message and does not see a solution,
he must locate correct information. Figure 13 presents the effects of in-
creased information search time on total error message processing time.
This increase might reflect the difference between consulting a readily
available handbook as opposed to a prolonged discourse with another opera-
tor. For sensitivity test purposes, information search time was varied be-
tween 10 and 180 seconds. The resulting error message processing times
ranged from 77 to 219 seconds. For the low and the intermediate conditions
tested, each one second increase in search time produced approximately 1.5
seconds in error message processing time. Accordingly, within the model
information search time exerts a greater effect than cognition and decision
time. This seems to be reasonable, especially if a manual or some outside
source must be consulted. The effect was largely linear, as would be antici-
pated since this search time is largely an additive function in the model.

When, as the result of the random walk logic, a solution to the problem
posed by the error message is reached, a revised message must be entered
into the computer. The probability that any given solution is correct should
have an effect on the time required to process error messages. Figure 14
shows the effect. Probabilities over the range of .10 to .90 were tested.
With this probability variation, the resultant mean time for error message
processing ranges from 96 to 551 seconds. The time increase was highly
correlated with probability decrease. This result was, of course, to be an-
ticipated due to the large number of random walk repetitions to be anticipated
from low probabilities. For example, a probability of .10 can be anticipated
to produce, on the average, approximately nine times as many repetitions as
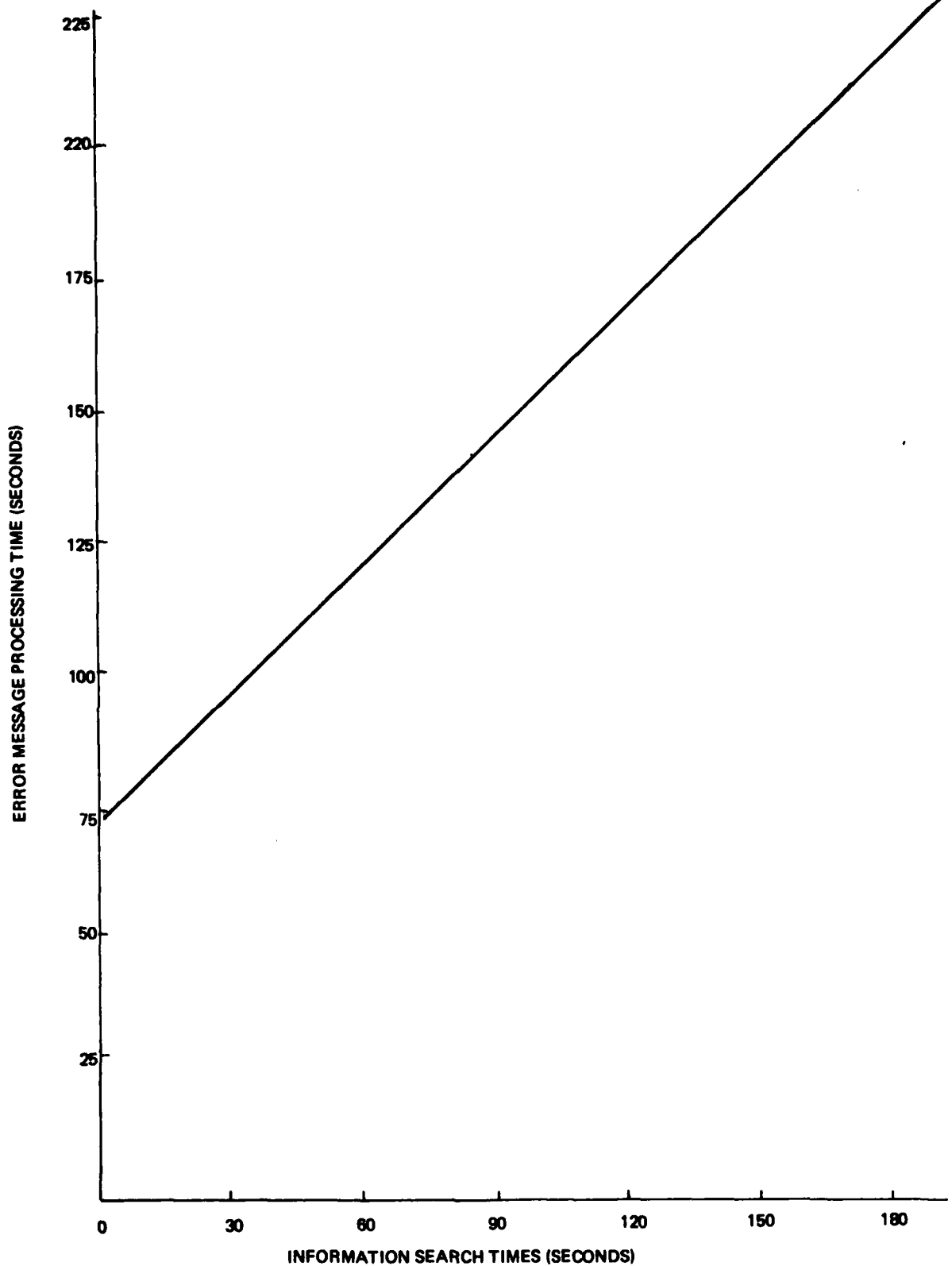a probability of .90 (number of repetitions = 1/probability of success).

FIGURE 13. EFFECT OF MEAN INFORMATION SEARCH TIMES ON ERROR
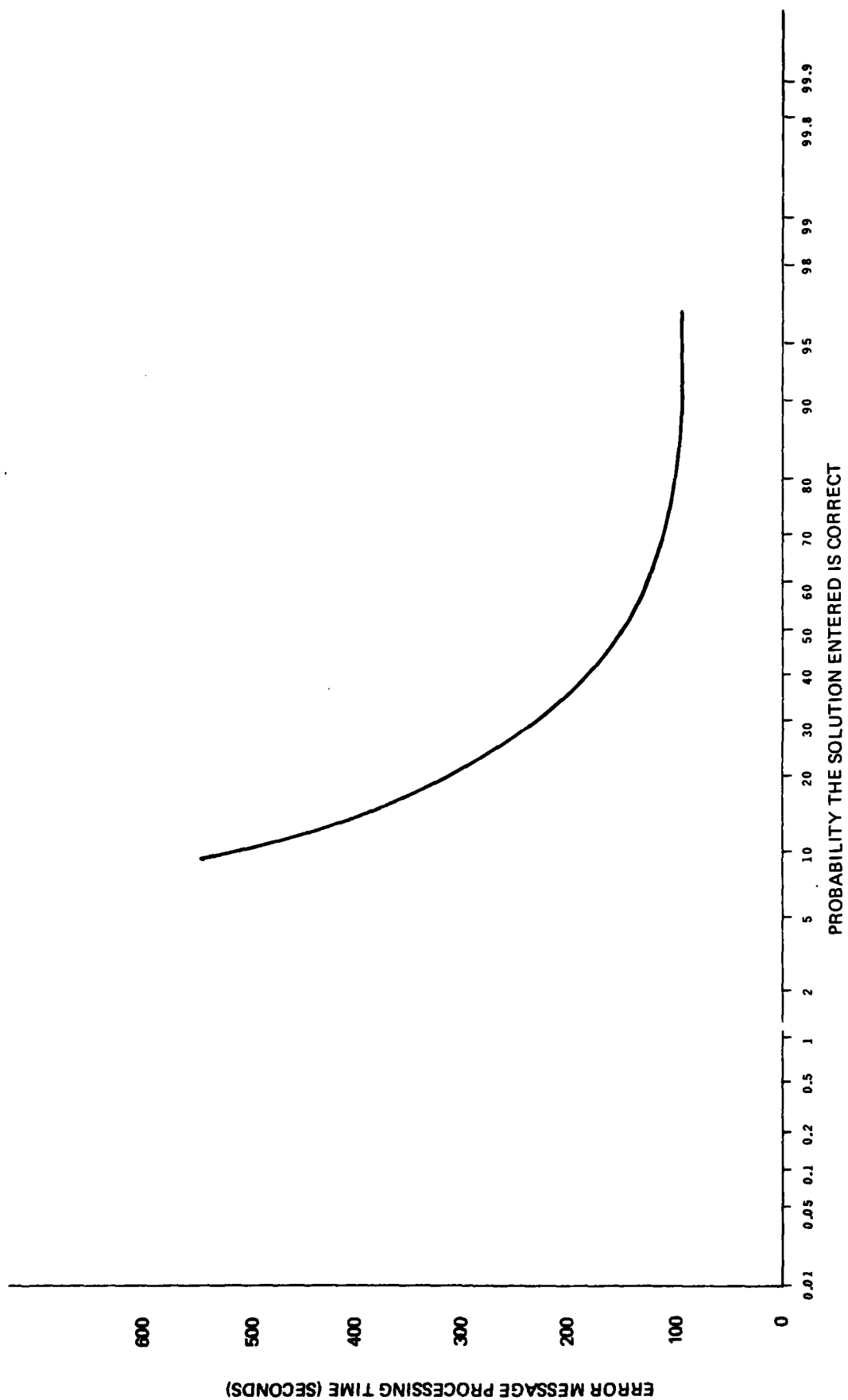MESSAGE PROCESSING TIMES

27

FIGURE 14. THE EFFECT OF PROBABILITY OF CHOOSING A CORRECT SOLUTION ON ERROR MESSAGE PROCESSING TIME

28

Combined Probability

As indicated in Figure 7, exit from the error message subroutine is dependent on two probabilities. The first of these probabilities is the input entry relative to the probability of moving toward or away from a solution at any step. The second probability is the probability that the achieved solution is correct. At this point in the logic, a random number (selected from a rectangular distribution) is compared with an input probability. The results of this comparison are employed to determine solution correctness. The effects of concurrent variations of these two probabilities were tested. The probability of reaching a solution was varied over the range from .10 to .90, while the input probability relative to solution correctness was varied over the same range. The results are presented in Figure 15. Again, directional trends were indicated in the anticipated direction. As anticipated, the effects of the combination, when both probabilities were low, was strong. Except for extreme values, error message processing time seems, within the model, to be about equally dependent on each of the two probability numbers involved. In the absence of empirical data to the contrary, this effect seems justifiable.

Other Tests of Sensitivity

Two other features tested in these sensitivity tests were the transmission delay simulation and the incoming message interruption simulation implemented in MANMOD. The transmission delay time is an additive to the time to perform the task and due to its relatively low value is usually minimum in comparison with the total task performance time. The effects were linear as anticipated from the logic involved.

Incoming messages of priority higher than routine interrupt the message in process (if any) and produce a delay. Test runs were made with an interruption duration of 60 seconds with a standard deviation of 2.5 seconds. Two conditions were compared: (1) interruption frequence of 5 times per hour, and (2) a frequency of 10 times per hour. These frequencies produced mean message processing times of 244.9 and 327.4 seconds. As seems reasonable, an increased frequency of interrupted messages caused an increased processing time for the original message. This increase reflects the increase in time required to repeat a part of the processing of an interrupted message, as well as the delay while waiting for the incoming message to get through.
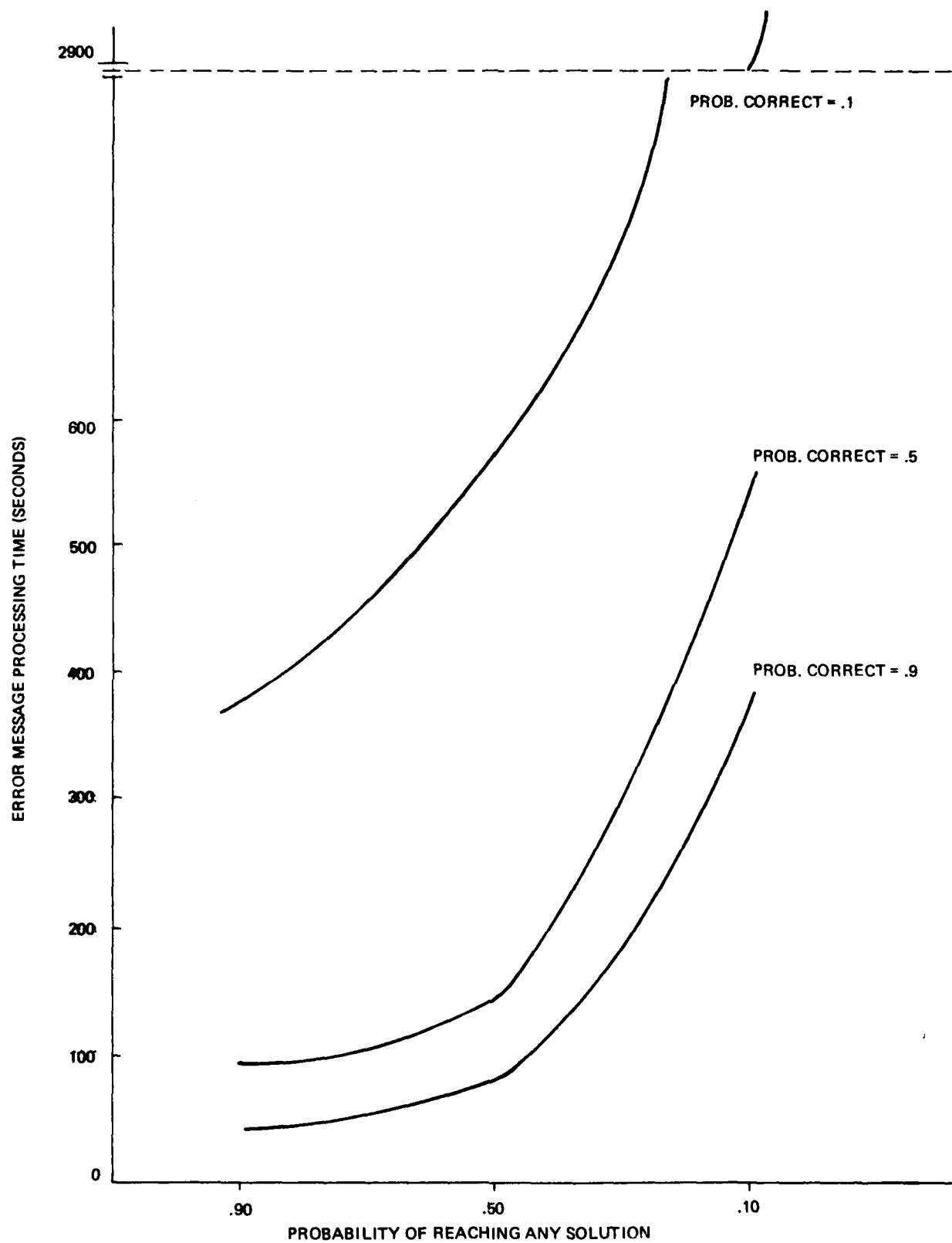
FIGURE 15. THE EFFECTS OF COMBINATION OF THE PROBABILITY OF REACHING
ANY SOLUTION AND THE SOLUTION BEING CORRECT
FOR ERROR MESSAGE PROCESSING TIMES

30

CHAPTER IV

DISCUSSION, SUMMARY, AND CONCLUSIONS

The goals of the present program were to couple the MANMOD, CASE, and SAMTOS models so that the strongest features of each can be exercised in an integrated TOS simulation and to strengthen the MANMOD so as to allow greater simulation fidelity. Both of these goals were achieved. The coupled CASE and MANMOD computer simulation may now be performed on the U 1108 system and the results entered directly to SAMTOS. This approach achieved the desired coupling without modifying SAMTOS in any way. Modification of the SAMTOS program was considered to be undesirable because SAMTOS is written in a special language and because certain subroutines in the model are not the sole property of the government. Accordingly, the cost of such a modification would exceed the benefit to be obtained from direct integration.

The MANMOD has been previously validated (Siegel, Wolf, & Leahy, 1973) and found to produce results which agree quite well with criterion data. There is little, if any, reason to believe that the coupling of MANMOD with CASE and the modifications introduced into MANMOD during the course of the present work will exert a negative influence on this previously suggested validity. However, continuous verification of such models is certainly desirable. At the minimum, it seems desirable to validate the newly implemented error message processing aspects of the MANMOD.

The results of the sensitivity tests indicated that the message processing time output is sensitive to variation of the input parameters which directly affect this logic. All tests completed supported the contention that these modifications yield an output in the anticipated direction. An assessment of whether or not the magnitudes indicated are realistic would depend on the availability of criterion data, as discussed above.

It seems, however, that the Army now has available a flexible simulation tool which can be used to assess various aspects of the TOS and similar communications systems. When the MANMOD itself and the coupled models are considered, there seems to be available the ability to simulate and investigate the effects of varying items such as qualitative and quantitative aspects of the manning, message load, equipment characteristics and delay times, message type, and watch length on system effectiveness. Moreover, the output will state not only that a given effectiveness level was or was not achieved but also what contributed to any failures noted. The output detail can provide insights relative to equipment design modification, training requirements and objectives, personnel requirements, and tradeoffs.

31

Summary and Conclusions

In order to provide a more powerful tool for simulating the TOS and similar communications systems, three previously developed and independent models were coupled. The three models considered were: MANMOD, CASE, and SAMTOS. In the coupled form, the message delay data generated by a revision of CASE are employed as input to the MANMOD. The MANMOD then employs these data within its simulation of the message processing by the system operators. The output of the combined simulation is in a form that it can be entered directly into SAMTOS, which simulates further equipment delay aspects.

During the course of the integration effort, a number of improvements were introduced into the logic of the MANMOD. These improvements were largely, but not exclusively, concerned with the simulation of error message processing. The modifications were tested for sensitivity and reasonableness of effect on model output. The modifications were believed to be acceptable from the point of view of both of these criteria.

The following conclusions seem to be indicated:

1. An integration has been attained of the MANMOD with a revised CASE and the SAMTOS models.

2. The combined model should allow the simulation of the effects of a host of human, message, and equipment parameters on the effectiveness of TOS and similar communication systems.

3. The various modifications of the MANMOD, implemented during the course of the present work, seem to produce effects which will serve to enhance model utility.

4. Validation of the newly developed effects seems required and calibration may be necessary.

32

REFERENCES

Baker, J.D., Mace, D.J., & McKendry, J.M. *The transform operation in TOS: Assessment of the human component.* BESRL Technical Research Note 212, AD697716, 1969.

Baker, J.D. Quantitative modeling for human performance in information systems. *Ergonomics,* 1970, *13,* 645-644.

Laming, D.R. *Information theory of choice-reaction times.* Academic Press: New York, 1968.

Leahy, W.R., Lautman, M.R., Wolf, J.J., Bearde, J.L., & Siegel, A.I. *A digital simulation model of message handling in the tactical operations system. III. Further extension of the model for increased interaction.* U.S. Army Research Institute: Research Memorandum 74-11, 1974.

Siegel, A.I., Wolf, J.J., & Leahy, W.R. *A digital simulation model of message handling in the tactical operations system: The model, its sensitivity and user's manual.* U.S. Army Research Institute: Research Memorandum 73-5, 1973. (a).

Siegel, A.I., Wolf, J.J., Leahy, W.R., & Bearde, J.L. *A digital simulation model of message handling in the tactical operations system: Extensions of the model for interactivity with subjects and experimenters.* U.S. Army Research Institute: Research Memorandum 7306, 1973. (b)

Smith, E.E., & Spoehr, K.T. The perception of printed English: A theoretical perspective. In B.H. Kantowitz (Ed.), *Human information processing: Tutorials in performance and cognition.* Wiley: New York, 1974.

Spoehr, K.T., & Smith, E.E. *Perceptual units and parsing process in word perception.* Paper presented at the meeting of the Psychonomic Society, St. Louis, November 1972.

Spoehr, K.T., & Smith, E.E. The role of syllables in perceptual processing. *Cognitive Psychology,* 1973, *5,* 71-89.

U.S. Army *Tactical operations system operable segment (TOS^2): Systems engineering study report.* Office of the Project Manager. U.S. Army Tactical Data Systems, April 1972.

APPENDIX

Description of Modified CASE Model for Integrated Simulation

David Eyestone
Systems Analysis Section
Plans and Analysis Division
U. S. Army Electronics Comand

GERTS QR Simulation of Message Traffic in a Computer System

A simulation of message traffic in a computer system was developed
to interface with the MANMODEL. The simulation yields system performance
measures such as message response times (waiting time plus service time)
and utilization statistics for equipment components of the computer system.
Summary measures and distributions resulting from the simulation model may
be provided as input to the MANMODEL. This enables man-machine relation-
ships modeled in the MANMODEL to include machine dependent times representa-
tive of a particular computer system configuration.

The simulation emphasizes queueing aspects of message flow through
computer system components and is accomplished with the GERTS QR simulator
(references 1,2 and 3). This simulator is tailored to the simulation of
Graphical Evaluation and Review Technique (GERT - references 4 and 6)
probabilistic networks and is FORTRAN based. The GERTS QR simulator combines
capabilities of previous GERTS simulators (references 5 and 6). These
capabilities include features for handling queues in the network and resource
limitations on activities in the network.

This appendix provides a short description of network simulation with
GERTS QR and then describes the example network model which was developed
to demonstrate the MANMODEL interface. A listing of required input for
GERTS QR is also provided as well as samples of the output report statistics
produced by the simulator for this example.

37

Network Representation for Simulation with GERTS QR

Basic features and notation associated with GERTS network simulation are described in references 2,5, and 6. The basic network features and specific capabilities of the GERTS QR simulator are briefly summarized here.

Networks are made up of nodes and branches which represent events and activities, respectively, from the process to be modeled. Source nodes initiate activities at the network origin while sink nodes terminate specific paths through the network. Various node types are available for regulating the flow of entities through the network and collecting statistics. Node output sides may be deterministic or probabilistic in the selection of branches to follow after node release. Thus, each branch in the network is characterized by a probability of selection as well as a time (constant or random variable) for activity performance given selection. In this manner, entities are initiated and pass through the network to termination for a pre-set number of network realizations. Statistics are collected during each pass through the network to include probabilities that events and activities of interest will be realized and the associated times for realization.

The specific capabilities of the GERTS QR simulator provide an additional node type, the queue node, and allow the association of resource requirements with each service activity following a queue node. Entities passing through the network may wait at designated queue nodes in the network for service at the queue facility. These service activities may require single or multiple homogeneous resources.

The programs of the GERTS QR simulator then allocate resources to service activities according to user supplied scheduling options and resource availability. Total resources available, by type, are specified as input by the user. Service

activities which have been released (predecessor activities in the network have been completed) are placed in a file pending a check of resource availability. Activities from this file for which resources are available are placed in a second file as candidates for scheduling. As activities are selected for accomplishment, resources are allocated and available resources reduced accordingly. Activities which cannot be scheduled following resource allocation to other activities are removed to the first file to wait for resources. This means that entities whose flow through the network is being simulated may be delayed (1) in queues waiting to enter a service activity and also (2) after entry to the service activity due to lack of sufficient resources.

Description of the Three Program Level Example Network

The network in Figure   -1 depicts the flow of entities (messages or jobs in this case) through the queues and resource constrained activities which represent the computer system for this example. Three program levels are modeled which represent the priority arrangement through which jobs are selected for computer execution. Program levels are a hardware feature of certain actual computers (Litton AN/GYK-12). A division of incoming jobs is also commonly based on memory requirements; such a division results in ordering jobs for memory partitions. In this example, program levels are modeled and each program level is allocated a separate memory region.

The example model assumes that a specific remote job entry location is of interest. The job stream entered from this location is termed foreground load while the remainder of the load simulated is termed background.

Activity 2-3 in the network initializes the background load while activity 2-4 initializes the foreground load. The foreground job stream emanates from node 4 and proceeds to queue node 9. Service activity 9-10 represents communications transmission to the computer location. The loop on node 4 determines the inter-arrival times for the foreground load stream. Node 8 is a statistics node to verfiy the input load inter-arrival times generated. From node 10, a probabilistic node, incoming jobs are routed to one of the three program levels according to a specified probability. Queue node 12 represents entry to program level 1 (first priority) for the foreground job stream. Queue nodes 14 and 16 represent entry to program levels 2 and 3, respectively.
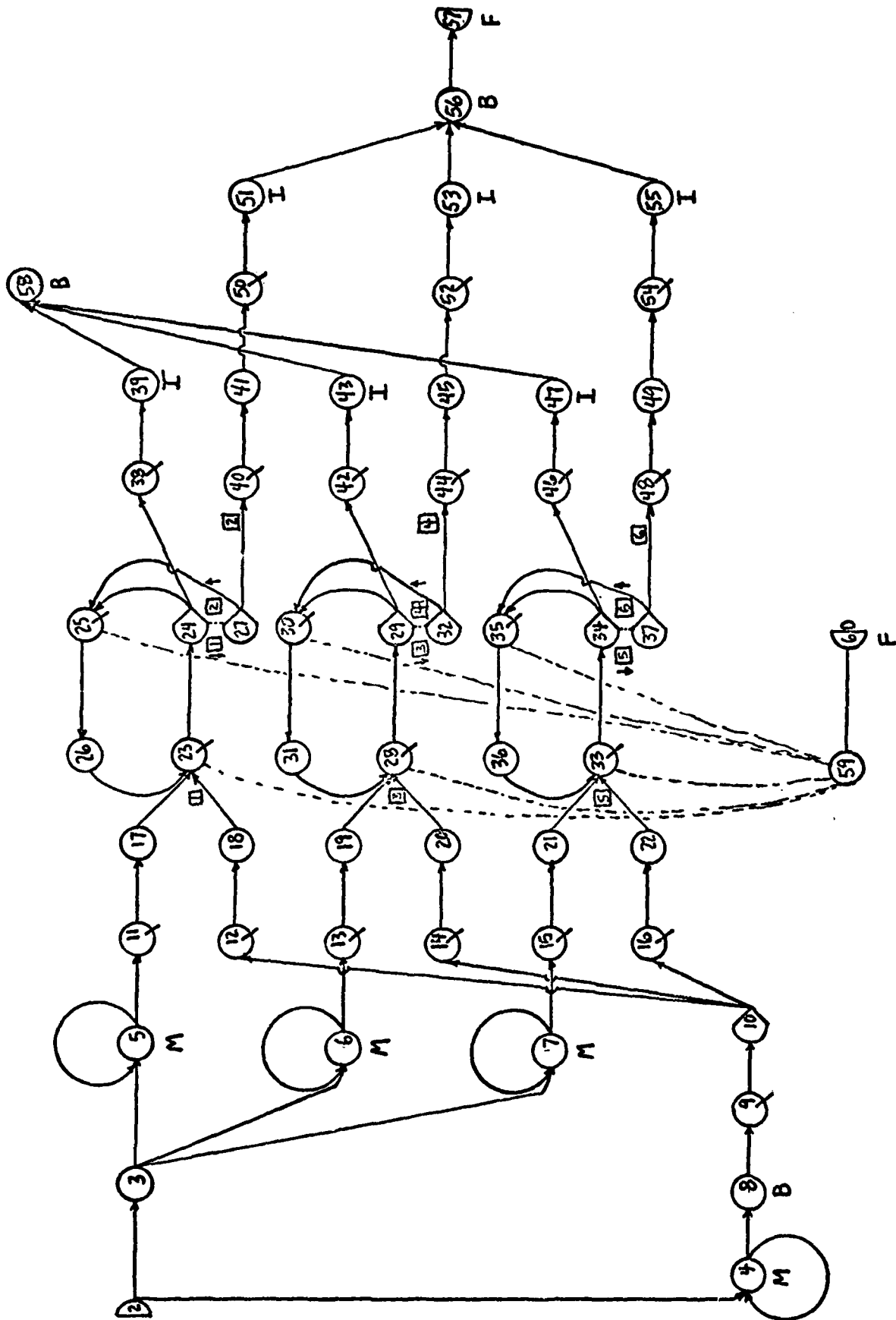
Figure -1: Network Diagram, Three Program Level Example

41

The network paths from node 12 to 41, 14-45, and 16-49 include activities v' _h represent computer processing for program levels 1-3 of the foreground job stream. As modeled, this computer processing first requires reading jobs into core from a random access device (RAD). Central processing unit (CPU) activity is then required followed by data accesses which may be required to the RAD with a specified probability. This CPU activity, random data access cycle continues in turn on an intermittent basis according to device availability until the job is completed. Upon completion, the job is read out to the RAD.

On the network diagram, service activity 12-18 represents the reading in of a program level 1 job from the foreground stream. Service activity 23-24 represents CPU activity while 25-26 represents RAD accesses. Job routing to queue node 25 is handled probabilistically from node 27 in the case of foreground jobs. Node 27 is placed into the network (replacing node 24) through the network node modification feature which allows node output changes during the course of the simulation. This allows foreground and background jobs to share the same queue nodes representing computer processing activities with a resulting savings in the size of the network to be simulated. When activity 27-40 is selected (according to the probability specified) the job has completed and activity 40-41 represents reading the job out to the RAD.

Following computer processing activities, the resulting output is transmitted back to the remote job entry site for jobs from the foreground stream. Service activities 50-51, 52-53 and 54-55 represent program level 1-3 output transmissions. At the conclusion of output

42

transmission, statistics are collected on the computer system response time. For the foreground stream this interval is collected for individual jobs on each of the three program levels. An I appears below nodes 51, 53 and 55 to designate an Interval statistics node. Interval statistics are collected at these points measured from the time the job was tagged at node 4, a Mark node, to indicate system entry time.

The background portion of the network allows simulation of the computer system load in addition to the remote job entry site of particular interest. Contention for resources between foreground jobs and the background job stream is represented in this manner. Background job loads may be adjusted on each of the three program levels, as represented by self-loops establishing inter-arrival times on nodes 5, 6 and 7 for program levels 1, 2 and 3, respectively. No communications transmissions are represented for the background job streams. Computer processing activities are handled in the same manner as discussed for the foreground jobs, with separate activities for reading background jobs in from and out to the RAD. For example, service activity 11-17 represents reading in program level 1 background jobs while 38-39 represents read out. This permits separate interval statistics to be collected on the simulated computer processing times for background jobs. Interval statistics are collected for each program level at nodes 39, 43 and 47. Between statistics (node 58) are then collected on all background jobs to assist in determining the output rate of the modeled system.

The network diagram also includes a "balk" node (59), to which jobs are routed if designated queue capacities are exceeded. Queue nodes in the computer processing portion of the network are designated as zero entry queues since only one job is allowed on each program level

(utilizing the corresponding memory region) at once. Jobs resident on
a level must either be in-process or waiting for resources (processor
or devices). In this situation, balking jobs constitute an error condi-
tion and realization of node 59 and 60 indicate the occurrence of such
an error during the course of a simulation run. Queue nodes 38, 40,
42, 44, 46 and 48 are also zero entry queues although links to node
59 have been excluded from the diagram.

Nodes 56 and 57 are utilized to produce an intermediate report
after a specified number of foreground jobs have been simulated and
final reports after a specified number of sets of foreground jobs have
been simulated. For example, node 56 may be realized after 50 jobs are
processed. This causes activity 56-57 to be accomplished producing
an intermediate report. Node 57 may be realized after 1, 5, 10 or some
other arbitrary number of sets of 50 jobs each. Node 57 (a sink
node) terminates the simulation on realization and produces final reports
for the total number of jobs simulated (50, 250, 500 etc.).

For this example, all queues are ordered on a first in first out (FIFO)
basis. Resource-allocation and scheduling files are also ordered on a FIFO
basis according to the time each job was tagged at a mark node designating
system entry time. Activities corresponding to program execution within
a memory region are further scheduled on a priority basis with program
level 1 receiving first priority. Activities are also screened to insure
single job occupancy in a memory region during read in, execution, and
read out operations requiring the CPU. Allocating resources to service
activities in order of priority and screening to hold a specific resource
over a series of service activities requires a user modification to the
standard GERTS QR scheduling subprogram. Additional user modifications

provide intermediate and final summary statistics tailored to the present example. Since the GERTS QR simulator is FORTRAN based, these modifications are readily accomplished.

Resources, by type, for the example are listed below:

Resource	Type	Number Available
CPU	1	1
Memory Region 1	2	1
Memory Region 2	3	1
Memory Region 3	4	1
Randon Access Devices	5	2
Communications Channel	6	1

The communications channel is required by service activities representing communications transmission to and from the computer location. For example, service activities 9-10 and 50-51 for program level 1 of the foreground job stream require the communications channel, resource type 6. Read in service activities (e.g. 12-18), from the RAD to core, require the CPU, corresponding memory region (1 for service activity 12-18), and one RAD (two are available). Service activities representing processing by the CPU (e.g., 23-24) require the CPU and the corresponding memory region (1). RAD accesses (e.g., service activity 25-26) require one RAD and the corresponding memory region (1). Read out service activities (e.g., 40-41) require the same resources as for reading into core.

This completes the description of the example network. Required input data for the simulator is next listed with the required card formats. Sample output report statistics from the example are then listed.

45

Required Input to the GERTS QR Simulator

Table   -1 lists required input card types and data fields for
the GERTS QR simulator. The GERTS QR programs are installed at Edge-
Wood Arsenal on the UNIVAC 1108 to interface with the MANMODEL.

DATA CARD O*

Field 1   Total number of jobs (entities) passing through
                 all queues (I5).

Field 2   Number of jobs in each set to be simulated between
                 calls to produce intermediate report statistics (I5).

Field 3   Set equal to 1 to produce intermediate report
                 statistics (I5).

Field 4   Not required (I5).

Field 5   Not required (I5).

Field 6   Not required (I5).

Field 7   Number of program levels (or priority levels)
                 for which jobs must be scheduled (I5).

DATA CARD 1

Field 1   The analyst's name (6A2,1).

Field 2   The project number (I4,1) (If negative, data
                 card 7 is required to indicate the runs to be
                 traced).

Field 3   The month number (I2,1).

Field 4   The day number (I2,1).

Field 5   The year (I4,1).

Field 6   The number of times the network is to be simulated
                 (I4,1).

Field 7   The number of activities with different time
                 characteristics (I4,1).

Field 8   The number of branches in the network plus an
                 estimate of the maximum number of activities which
                 can occur simultaneously (I4,1).

*Note: Only fields 3 and 7 are required since PURGE options are not
        exercised in this version. For three program level example,
        a 1 is required in col 15 and a 3 in col 35.

| Field 9 | An integer random number seed (I18,1). Right justified to col. 54. |

| Field 10 | A floating point random number seed (F10.4,1). Not required for this version. |

DATA CARD 2

| Field 1 | The largest node number of the network including all possible modifications to the network (I3,1) Note: the smallest node number permitted is 2. |

| Field 2 | Number of source nodes (I3,1). |

| Field 3 | Number of sink nodes (I3,1). |

| Field 4 | Number of sink nodes that must be realized before the network is realized (I3,1). |

| Field 5 | Number of nodes which statistics are to be collected on, including all sink nodes (I3,1). |

| Field 6 | Number of types of counts (I3,1). |

| Field 7 | A 1 if network modifications exist; a 0 otherwise (I3,1). |

| Field 8 | Number of different resource types (I3,1). |

| Field 9 | The attribute on which ranking is to be done for files NOQ and (NOQ-1). Add 100 to attribute number if a JTRIB value is to be ranked on (I3,1). |

| Field 10 | The priority system to be used for files NOQ and (NOQ-1). A 1 indicates low-value first. A 2 indicates high-value first (I3,1). |

| Field 11 | Number of available resources of Type 1 (I3,1). |

| Field 12 | Number of available resources of Type 2 (I3,1). |

| Field 13 | Number of available resources of Type 3 (I3,1). |

.
.
.

| Field 20 | Number of available resources of Type 10 (I3,1). Maximum of 10 resource types for this version. |

48

DATA CARD 3
One data card for each node in the network.

Field 1   The node number (descriptor) associated with the node characteristics given on this card (I3,1).

Field 2   Special characteristic of the node. Codes for special characteristics are:

1. Source node
2. Sink node
3. Node on which statistics are collected
4. A mark node
5. Q Node-See description for Q-Nodes which follows

If Field 2 is left blank, so special characteristic is associated with the node (I3,1).

Field 3   The number of releases required to realize the node for the first time. (I3,1).

Field 4   The number of releases required to realize the node after the first realization (I3,1).

Field 5   Output characteristic of the node. Codes for input are: P for Probabilistic; and D for Deterministic (A1,1).

Field 6   If events that have been scheduled to end on this node are to be removed (cancelled) when this node is realized, an "R" should be put in this field. If removal isnot desired, leave blank (A1,1).

Fields 7, 8 and 9 are used only if

The node is a sink node or a statistics node (code 2 or 3 in field 2).

Field 7   The lower limit of the second cell for the histogram to be obtained for this node. The first cell of the histogram will contain the number of times thenode was realized in a time less than the value given in this field (F6.2,1).

Field 8   The width of each cell of the histogram. Each histogram contains 20 cells. The last cell will contain the number of times the node was realized in a time greater than or equal to the lower limit (specified in Field 7) + 18 * (cell width (specified by Field 8)) (F6.2,1).

49

Field 9	Statistical quantities to be collected (A1,1)

<blank>

      F. The time for <u>first</u> realizations of the node
      A. The time of <u>all</u> realizations of the node
      B. The time <u>between</u> realizations of the node
      I. The time <u>interval</u> required to go between
         two nodes
      D. The time <u>delay</u> from first activity completion
         on the node until the node is realized

Field 10   Only required for Q nodes. See <u>For Q-Nodes</u> description which follows (I3,1).

Field 11   Only required for Q nodes. See <u>For Q-Nodes</u> Description which follows (I3,1).

Field 12   Histogram plot and copy option. Set to 1 to plot histogram for node described. Also copies histogram identification and frequency counts to attached external file (I3,1).

<u>Data Card 3A</u>

<u>For Q-Nodes</u>

Field 1   Same as for Data Card 3 described above.

Field 2   Code for a Q-node is 5.

Field 3   For a Q-node, the initial number in the queue. If greater than zero, the service activity is assumed busy and an end of service activity event is defined automatically.

Field 4   For a Q-node, -1 to indicate maximum number in queue is 0, 0 to indicate no limit on number in the queue, otherwise the maximum number allowed in the queue.

Field 5,6   Not required for Q-nodes.

Field 7, 8   Lower limit of cell 2 and width of each cell for statistics on the average number in the queue.

Field 9   Not required for Q-nodes.

Field 10   Priority Ranking Procedure for the Q-nodes (I3,1)
        0 - First-in - first-out (FIFO)
        1 - Last-in - first-out (LIFO)

Field 11   Node that is transferred to when an activity is
                            completed that is incident to the Q-node and
                            the maximum number allowed is in the queue
                            (the node to which an item balks) (I3,1).

Field 12   Same as for Data Card 3 described above.

NOTE: The last card of this type must have a zero in Field 1 .

DATA CARD 4

                            The parameters associated with the distribution
                            of the time to perform each activity. One card
                            is required for each activity with a different
                            time characterization. The number of cards is
                            specified by Data Card 1, Field 7. A maximum
                            of 30 is permitted. The cards must be arranged
                            by ascending parameter number and the parameters
                            must be numbered consecutively or blank cards
                            appropriately placed. Eleven distribution types
                            are available which are:
                                1. Constant
                                2. Normal
                                3. Uniform
                                .4. Erlang (Exponential optional)
                                5. Lognormal
                                6. Poisson
                                7. Beta
                                8. Gamma
                                9. Beta (Fitted to three parameters as in PERT).
                               10. Triangular
                               11. Hyper-exponential (For given values of overdispersion).
                            The fields required are dependent on the distribution
                            type of activity. See Definitions of Parameters
                            for Random Deviate Sampling following this description
                            of input data formats.

DATA CARD 5

One data card for each activity associated with the network.

Field 1   Probability of realization (F8,3,1).

Field 2   Start node (I3,1).

Field 3   End node (I3,1).

Field 4   Parameter number (I3,1).

51

DATA CARD 5 (Continued)

Field 5   The distribution type (I3,1).

Field 6   Count type (I3,1).

Field 7   Activity number (I3,1).

Field 8   Number of resources of type 1 required for the
                           activity (I3,1).

Field 9   Number of resources of type 2 required for the
                           activity (I3,1).

Field 10   Number of resources of type 3 required for the
                           activity (I3,1).

.
.
.

Field 17   Number of resources of type 10 required for the
                           activity (I3,1).

NOTE: The last data card of this type must have a zero (or blank)
        in Field 2.

DATA CARD 6 (Optional)

Only required if network modifications exist, i.e., if the number of
nodes modified is greater than zero. (Field 7, Data Card 2).

Field 1   An activity number (I3,1).

Field 2   The number of the node to be replaced if the
                           activity given in Field 1 is realized (I3,1).

Field 3   The number of the node to be inserted into the
                           network in place of the node specified in Field 2
                           when the activity in Field 1 is realized (I3,1).

Fields
4-21   Field 2 and 3 are repeated if the activity given
                           in Field 1 affects multiple nodes. A zero in an
                           even-numbered field indicates the end of the data
                           on the card.

NOTE: The last card of this type must have a zero in Field 1.

DATA CARD 7 (Optional)

Only used if the project number is negative*. (Field 2, Data Card 1).

Field 1   The run number for which tracing of the end of
                            activity events should begin (I3,1).

Field 2   The run number for which tracing of the end of
                            activity events should terminate (I3,1).

* Negative project number produces TRACE option, a debugging aid. Each
activity realized during the course of the TRACE produces two lines
of printed output. To avoid reams of output, care must be exercised
when the TRACE option is elected to limit the total number of activities
simulated.

Multiple networks can be analyzed by stacking the data cards as described
above, one after another. No blank cards should separate the data
cards for each network.

NOTE: Two blank cards are required to indicate the end of all networks
        to be simulated.

Definitions of Parameters for Random Deviate Sampling

The parameters required on Data Card Type 4 to sample from the nine distributions available in GERTS III are described below.

For distribution type 1 (Constant):

Field 1   The constant time (F10.4,1).

For distribution type 2 (Normal); 5(Lognormal); 7 (Beta); and 8(Gamma):

Field 1   The mean value (F10.4,1).

Field 2   The minimum value (F10.4,1).

Field 3   The maximum value (F10.4,1).

Field 4   The standard deviation (F10.4,1).

For distribution type 3 (Uniform):

Field 1   Not used (F10.4,1).

Field 2   The minimum value (F10.4,1).

Field 3   The maximum value (F10.4,1).

Field 4   Not used (F10.4,1).

For distribution type 4 (Erlang):

Field 1   The mean time for the Erlang variable divided
                   by the value given to Field 4 (F10.4,1).

Field 2   The minimum value (F10.4,1).

Field 3   The maximum value (F10.4,1).

Field 4   The number of exponential deviates to be included
                   in the sample obtained from the Erlang distribution
                   (F10.4,1).

If Field 4 is set equal to 1, an exponential deviate will be obtained
from distribution type 4.

For distribution type 6 (Poisson):

Field 1   The mean minus the minimum value (F10.4,I).

Field 2   The minimum value (F10.4,1).

Field 3   The maximum value (F10.4,1).

Field 4   Not used (F10.4,1).

Care is required when using the Poisson since it is not usually used
to represent an interval of time. The interpretation of the mean should
be the mean number of time units per time period.

For distribution type 9 (Beta fitted to 3 values as in Pert) and 10
(Triangular):

Field 1   The most likely value, m (F10.4,1).

Field 2   The optimistic value, a (F10.4,1).

Field 3   The pessimistic value, b (F10.4,1).

Field 4   Not used

For distribution type 11 (Hyperexponential):

Field 1   The mean value (F10.4,1).

Field 2   The minimum value (F10.4,1).

Field 3   The maximum value (F10.4,1).

Field 4   The standard deviation which should be greater
                           than Field 1. The amount by which the standard
                           deviation exceeds the mean reflects the amount
                           of overdispersion to be produced by sampling
                           from two parallel exponential random processes.

NOTE: Samples are obtained from the distributions such that if a sample
is less than the minimum value, the sample value is given the minimum
value. Similarly, if the sample is greater than the maximum value,
the sample value is assigned the maximum value. This is not sampling
from a truncated distribution but sampling from a distribution with a
given probability of obtaining the minimum and maximum values.

55

Sample Output Reports of the GERTS QR Simulator

Table ˙ -2 lists sample output from a simulation run of the three
program level example network. Sections of the intermediate reports
and final results for the simulation run are displayed in Table   -2
under these labels. A final output report tailored to the example is also
labeled and illustrated.

INTERMEDIATE REPORTS FOR RUN 1

PROGRAM LEVEL	JOBS PROCESSED	MEAN FLOW TIME(MIN)	STD DEV FLOW TIME	MEAN WAIT TIME	RESPONSE RATIO
1	21.00	.8568	.6324	.6202	3.6209
2	28.00	3.0897	2.7630	2.5518	5.7441
3	51.00	21.3836	13.3549	20.1839	17.8243
1	41.00	.9872	.7621	.6989	3.4242
2	52.00	2.4719	2.3316	1.9203	4.4816
3	107.00	41.0205	22.3225	39.5992	28.8605
1	60.00	.9678	.7157	.6286	2.8530
2	81.00	2.1729	2.1204	1.6767	4.3786
3	159.00	55.6463	28.3450	55.5003	301.2700

57

GERT SIMULATION PROJECT 1 BY 3 PR LVL EX
DATE 1/-30/-1975

FINAL RESULTS FOR 1 SIMULATIONS

NODE	PROB./COUNT	MEAN	STD.DEV.	# OF OBS.	MIN.	MAX.	NODE TYPE
57	1.0000	978.1504	.0000	1.	978.1504	978.1504	F
60	0	NO VALUES RECORDED					
58	1.0000	.3199	.3536	3057.	.0050	3.9492	B
56	1.0000	320.6492	15.4074	2.	309.7545	331.5439	B
55	1.0000	55.6463	28.3450	159.	.2907	105.3389	I
53	1.0000	2.1729	2.1204	81.	.1691	8.4422	I
51	1.0000	.9678	.7157	60.	.1870	4.1295	I
47	1.0000	54.9635	29.9679	1740.	.0668	108.7556	I
43	1.0000	2.0211	2.0269	839.	.0211	11.6056	I
39	1.0000	.9009	.8045	479.	.0204	5.1300	I
8	1.0000	3.1333	4.3484	311.	.0305	25.0000	B

QUEUE NODES

NODE	MEAN	STD.DEV.	# OF OBS.	MIN.	MAX.	
15	107.4066	.0000	1.	107.4066	107.4066	AVERAGE NUMBER IN THE QUEUE
15	.0089	.0000	1.	.0089	.0089	AVERAGE BUSY TIME OF PROCESSOR
15	.0000	.0000	1.	.0000	.0000	AVERAGE BALKERS PER UNIT TIME
15	54.0153	.0000	1.	54.0153	54.0153	AVERAGE TIME IN QUEUE
16	8.7709	.0000	1.	8.7709	8.7709	AVERAGE NUMBER IN THE QUEUE
16	.0008	.0000	1.	.0008	.0008	AVERAGE BUSY TIME OF PROCESSOR
16	.0000	.0000	1.	.0000	.0000	AVERAGE BALKERS PER UNIT TIME
16	50.1713	.0000	1.	50.1713	50.1713	AVERAGE TIME IN QUEUE

Final Results for Resource Utilization

RESOURCE	AVERAGE	STD.DEV.	# OF OBS.	MIN.	MAX.	
1	.6977	.0000	1.0000	.6977	.6977	
2	.1271	.0000	1.0000	.1271	.1271	
3	.2789	.0000	1.0000	.2789	.2789	
4	.7393	.0000	1.0000	.7393	.7393	
5	.4819	.0000	1.0000	.4819	.4819	
6	.0341	.0000	1.0000	.0341	.0341	
	.1766	.0000	1.0000	.1766	.1766	AVERAGE TIME SPENT IN NOG.1 FILE
					18644	JOBS DELAYED FOR RESORCES

FINAL OUTPUT REPORT

QUEUE	ENTRIES	RESOURCE WAIT TIME	PERCENTAGE
9	312	.73	.02
11	479	123.12	3.75
12	60	15.96	.49
13	839	453.27	13.80
14	81	89.67	2.73
15	1945	958.44	29.18
16	171	893.83	27.21
23	2894	99.11	3.02
25	2355	65.12	1.98
28	4608	200.03	6.09
30	3888	106.44	3.24
33	4732	40.34	1.23
35	2632	19.00	.58
38	479	20.05	.61
40	60	2.47	.08
42	839	47.02	1.43
44	31	2.75	.08
46	1740	135.03	4.11
48	159	11.34	.35
50	60	.06	.00
52	81	.44	.01
54	152	.24	.24

References:

1. Maggard, M.J., et al., "Network Analysis with GERTS III QR," *Industrial Engineering*, (6) #5, May 1974.

2. Hogg, Gary L., et al., "GERTS QR: A Model for Multi-Resource Constrained Queueing Systems Part I: Concepts, Notation and Examples," *AIIE Transactions*, (7) #2, June 1975

3. Hogg, Gary L., et al., "GERTS QR: A Model for Multi-Resource Constrained Queueing Systems Part II: An Analysis of Parallel-Channel, Dual-Resource Constrained Queueing Systems with Homo-geneous Resources," *AIIE Transactions*, (7) #2, June 1975.

4. Pritsker, A.A.B., "GERT· Graphical Evaluation and Review Technique," Memorandum RM-4973-NASA. The Rand Corporation, April 1966.

5. Pritsker, A.A.B. and R.R. Burgess, "The GERT Simulation Programs: GERTS III, GERTS III Q, GERTS III C, and GERTS III R" NASA/ERC Contract NAS-12-2113, Virginia Polytechnic Institute, May 1970.

6. Whitehouse, G.E., *Systems Analysis and Design Using Network Techniques*, Prentice-Hall, Englewood Cliffs, NJ, 1973.

DISTRIBUTION

ARI Distribution List

4 OASD (M&RA)
2 HQDA (DAMI-CSZ)
1 HQDA (DAPE-PBR)
1 HQDA (DAMA-AR)
1 HQDA (DAPE-HRE-PO)
1 HQDA (SGRD-ID)
1 HQDA (DAMI-DOT-C)
1 HQDA (DAPC-PMZ-A)
1 HQDA (DACH-PPZ-A)
1 HQDA (DAPE-HRE)
1 HQDA (DAPE-MPO-C)
1 HQDA (DAPE-DW)
1 HQDA (DAPE-HRL)
1 HQDA (DAPE-CPS)
1 HQDA (DAFD-MFA)
1 HQDA (DARD-ARS-P)
1 HQDA (DAPC-PAS-A)
1 HQDA (DUSA-OR)
1 HQDA (DAMO-RQR)
1 HQDA (DASG)
1 HQDA (DA10-PI)
1 Chief, Consult Div (DA-OTSG), Adelphi, MD
1 Mil Asst. Hum Res, ODDR&E, OAD (E&LS)
1 HQ USARAL, APO Seattle, ATTN: ARAGP-R
1 HQ First Army, ATTN: AFKA-OI-TI
2 HQ Fifth Army, Ft Sam Houston
1 Dir, Army Stf Studies Ofc, ATTN: OAVCSA (DSP)
1 Ofc Chief of Stf, Studies Ofc
1 DCSPER, ATTN: CPS/OCP
1 The Army Lib, Pentagon, ATTN: RSB Chief
1 The Army Lib, Pentagon, ATTN: ANRAL
1 Ofc, Asst Sect of the Army (R&D)
1 Tech Support Ofc, OJCS
1 USASA, Arlington, ATTN: IARD-T
1 USA Rsch Ofc, Durham, ATTN: Life Sciences Dir
2 USARIEM, Natick, ATTN: SGRD-UE-CA
1 USATTC, Ft Clayton, ATTN: STETC-MO-A
1 USAIMA, Ft Bragg, ATTN: ATSU-CTD-OM
1 USAIMA, Ft Bragg, ATTN: Marquat Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Lib
1 US WAC Ctr & Sch, Ft McClellan, ATTN: Tng Dir
1 USA Quartermaster Sch, Ft Lee, ATTN: ATSM-TE
1 Intelligence Material Dev Ofc, EWL, Ft Holabird
1 USA SE Signal Sch, Ft Gordon, ATTN: ATSO-EA
1 USA Chaplain Ctr & Sch, Ft Hamilton, ATTN: ATSC-TE-RD
1 USATSCH, Ft Eustis, ATTN: Educ Advisor
1 USA War College, Carlisle Barracks, ATTN: Lib
2 WRAIR, Neuropsychiatry Div
1 DLI, SDA, Monterey
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-MR
1 USA Concept Anal Agcy, Bethesda, ATTN: MOCA-JF
1 USA Arctic Test Ctr, APO Seattle, ATTN: STEAC-PL-MI
1 USA Arctic Test Ctr, APO Seattle, ATTN: AMSTE-PL-TS
1 USA Armament Cmd, Redstone Arsenal, ATTN: ATSK-TEM
1 USA Armament Cmd, Rock Island, ATTN: AMSAR-TDC
1 FAA-NAFEC, Atlantic City, ATTN: Library
1 FAA-NAFEC, Atlantic City, ATTN: Human Engr Br
1 FAA Aeronautical Ctr, Oklahoma City, ATTN: AAC-44D
2 USA Fld Arty Sch, Ft Sill, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: Library
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DI-E
1 USA Armor Sch, Ft Knox, ATTN: ATSB-DT-TP
1 USA Armor Sch, Ft Knox, ATTN: ATSB-CD-AD

2 HQUSACDEC, Ft Ord, ATTN: Library
1 HQUSACDEC, Ft Ord, ATTN: ATEC-EX-E-Hum Factors
2 USAEEC, Ft Benjamin Harrison, ATTN: Library
1 USAPACDC, Ft Benjamin Harrison, ATTN: ATCP-HR
1 USA Comm-Elect Sch, Ft Monmouth, ATTN: ATSN-EA
1 USAEC, Ft Monmouth, ATTN: AMSEL-CT-HDP
1 USAEC, Ft Monmouth, ATTN: AMSEL-PA-P
1 USAEC, Ft Monmouth, ATTN: AMSEL-SI-CB
1 USAEC, Ft Monmouth, ATTN: C, Facl Dev Br
1 USA Materials Sys Anal Agcy, Aberdeen, ATTN: AMXSY-P
1 Edgewood Arsenal, Aberdeen, ATTN: SAREA-BL-H
1 USA Ord Ctr & Sch, Aberdeen, ATTN: ATSL-TEM-C
2 USA Hum Engr Lab, Aberdeen, ATTN: Library/Dir
1 USA Combat Arms Tng Bd, Ft Benning, ATTN: Ad Supervisor
1 USA Infantry Hum Rsch Unit, Ft Benning, ATTN: Chief
1 USA Infantry Bd, Ft Benning, ATTN: STEBC-TE-T
1 USASMA, Ft Bliss, ATTN: ATSS-LRC
1 USA Air Def Sch, Ft Bliss, ATTN: ATSA-CTD-ME
1 USA Air Def Sch, Ft Bliss, ATTN: Tech Lib
1 USA Air Def Bd, Ft Bliss, ATTN: FILES
1 USA Air Def Bd, Ft Bliss, ATTN: STEBD-PO
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Lib
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: ATSW-SE-L
1 USA Cmd & General Stf College, Ft Leavenworth, ATTN: Ed Advisor
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: DepCdr
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: CCS
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCASA
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACO-E
1 USA Combined Arms Cmbt Dev Act, Ft Leavenworth, ATTN: ATCACC-CI
1 USAECOM, Night Vision Lab, Ft Belvoir, ATTN: AMSEL-NV-SD
3 USA Computer Sys Cmd, Ft Belvoir, ATTN: Tech Library
1 USAMERDC, Ft Belvoir, ATTN: STSFB-DQ
1 USA Eng Sch, Ft Belvoir, ATTN: Library
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL-TD-S
1 USA Topographic Lab, Ft Belvoir, ATTN: STINFO Center
1 USA Topographic Lab, Ft Belvoir, ATTN: ETL-GSL
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATS-CTD-MS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TE
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TEX-GS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTS-OR
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-DT
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-CTD-CS
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: DAS/SRD
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: ATSI-TEM
1 USA Intelligence Ctr & Sch, Ft Huachuca, ATTN: Library
1 CDR, HQ Ft Huachuca, ATTN: Tech Ref Div
2 CDR, USA Electronic Prvg Grd, ATTN: STEEP-MT-S
1 HQ, TCATA, ATTN: Tech Library
1 HQ, TCATA, ATTN: AT CAT-OP-Q, Ft Hood
1 USA Recruiting Cmd, Ft Sheridan, ATTN: USARCPM-P
1 Senior Army Adv., USAFAGOD/TAC, Elgin AF Aux Fld No. 9
1 HQ, USARPAC, DCSPER, APO SF 96558, ATTN: GPPE-SE
1 Stimson Lib, Academy of Health Sciences, Ft Sam Houston
1 Marine Corps Inst., ATTN: Dean-MCI
1 HQ, USMC, Commandant, ATTN: Code MTMT
1 HQ, USMC, Commandant, ATTN: Code MPI-20-28
2 USCG Academy, New London, ATTN: Admission
2 USCG Academy, New London, ATTN: Library
1 USCG Training Ctr, NY, ATTN: CO
1 USCG Training Ctr, NY, ATTN: Educ Svc Ofc
1 USCG, Psychol Res Br, DC, ATTN: GP 1/62
1 HQ Mid-Range Br, MC Det, Quantico, ATTN: P&S Div

61

62